GEOPHYSICAL INVESTIGATIONS AT THE SAND CREEK MASSACRE SITE, COLORADO

by

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INTRODUCTION

From May 18 to May 26, the National Park Service conducted an archeological investigation of Sand Creek Massacre site in Kiowa County, Colorado (Figure 1). In addition to the metal detector reconnaissance survey of the project area, geophysical investigations were conducted on a portion of the probable Cheyenne village location in order to provide an assessment of these applications to future archeological investigations of the site (Research Design to Locate the Site of the Sand Creek Massacre, Kiowa County, Colorado, dated April 30, 1999). Four twenty by twenty meter (20 x 20 m) grids were established on a portion of the William Dawson property along the western boundary of the village location (Scott 1999). Approximately ten artifacts were identified and collected during the metal detector sweep of the area. Three types of geophysical surveys were conducted over this area. They included a magnetic gradient survey with a Geoscan Research FM36 fluxgate gradiometer, a soil conductivity survey with a Geonics EM38 ground conductivity meter, and a high sensitivity metal detection survey with a time-phase Geonics EM61 high sensitivity metal detector.

ENVIRONMENTAL SETTING

The artifact concentration associated with the Sand Creek Massacre Site village location is situated on a terrace above the left bank of the Big Sandy Creek in Section 24, Township 17 South, Range 46 West, in Kiowa County, Colorado (Figure 2). It lies at and elevation of approximately 3980 feet above mean sea level. The project location is within the Colorado Piedmont of the Great Plains Province (Fenneman 1931:30-37). The region surrounding the project area is nearly level to gently sloping uplands where the dominant slope is less than three percent. The Big Sandy Creek valley is surrounded by rolling uplands with slopes greater than three percent. The valley floor is nearly level, rolling, or shaped like sand dunes. Sand hills border the Big Sandy Creek in several locations near the present project location.

The soils within the Big Sandy Creek valley belong to the Bankard-Fluvaquents soil association (Anderson et al. 1981:8). The soils within this association are "nearly level, somewhat excessive drained to poorly drained, deep soils, on terraces and flood plains" (Anderson et al. 1981:8). Anderson et al. (1981:17-18, 58, Sheet No. 7) identifies the soil mapping unit as nearly level fluvaquents (soil mapping unit 12). These soils are somewhat poorly drained to poorly drained. These soils formed in mixed alluvium. A more detailed analysis of the geomorphology is presently being conducted by LaRamie Soils Service, Laramie, Wyoming (Holmes and McFaul 1999). The initial analysis of a portion of the Dawson property by Homes and McFaul (1999) would apparently place the village site on the T1 terrace.

The project location also lies within the Kansan biotic province of North America (Dice 1943:26-27). This area is part of the shortgrass prairie region of the semiarid Great Plains (Brown 1985:54-63; Shelford 1963:344-347). Climax vegetation is identified as a mixture of short grasses and grasses of mid-height (Clements and Shelford 1939:260-264). Overgrazing has resulted in the removal of the midgrasses. Important short grasses

include blue grama and buffalo grass. Midgrasses include needle-and-thread grass and bluestem. Many grasses have adapted a bunch habit in the more arid portions of the province. Numerous flowering annual and perennials are also found throughout the Kansan biotic province. Trees are rare but do occur along major rivers and smaller streams where a viable source of water is present. Groves of cottonwoods and other deciduous trees are present in these locations.

Bison was the dominate animal until the late nineteenth century when they were decimated and cattle were introduced (Shelford 1963:344-347). The pronghorn antelope remains one of the dominant wild animal species. Lesser influents include black-tailed jack rabbits, badgers, coyotes, and prairie dogs (Brown 1985:62-63). Numerous rodents are also present. Larks, sparrows, owls, and hawks are present. Plains garter snake and the western rattlesnake, and bullsnake represent the major reptiles present in the province. While grasshoppers are one of the more abundant groups of insects, numerous species are present throughout the region.

The region is subject to rather cold winters and fairly hot summers (Anderson et al. 1981:1-2). The average winter temperature is 32° F with an average daily minimum temperature of 17° F (Anderson et al. 1981:82). During the summer, the average monthly temperature is 74° F with an average daily maximum temperature of 90° F. Record temperatures have ranged from -25° F in the winter of 1963 to 110° F in the summer of 1963 (recorded at Eads, Colorado). The annual precipitation averages 14 inches (Anderson et al. 1981:82). The majority of the precipitation falls as rain during the warm months of April through September. Thunderstorms are common with occasional hailstorms. Snowstorms occur every winter with an average seasonal snowfall of 27 inches. During the course of the present investigations, the region had received substantial amounts of rainfall prior to the investigations that caused the Big Sandy to flood.

GEOPHYSICAL TECHNIQUES

Three separate geophysical investigations were conducted across the geophysical grid. These included a magnetic survey with a Geoscan Research FM36 fluxgate gradiometer, a Geonics EM 38 ground conductivity meter, and a Geonics EM61 high sensitivity metal detector. Of the three methods used at the village site, the magnetic gradient investigation represented a passive geophysical technique (Heimmer and De Vore 1995:7). The conductivity and the high sensitivity metal detection investigations were active geophysical techniques (Heimmer and De Vore 1995:9).

Passive techniques measure the physical property of naturally occurring local or planetary fields created by earth related processes under study. The primary method used in archeology is magnetic surveying. Active techniques transmit an electrical, electromagnetic, or acoustic signal into the ground. The interaction of these signals and buried materials produces an altered return signal that is measures by the appropriate geophysical instrument. The ground conductivity meter and the high sensitivity metal detector utilize electromagnetic signals.

Authors, Anthony Clark (1996), and Don H. Heimmer and Steven L. De Vore (1995), discuss the basic concepts of electromagnetic conductivity (conductivity) and magnetic (magnetometry) surveys. Melissa Connor and Douglas D. Scott (1998) provide and introduction to the use of metal detectors in archeological investigations. Field methodology is discussed in Geoscan Research's instruction manuals for the RM15 resistance meter (Geoscan Research 1993) and the FM36 fluxgate gradiometer (Geoscan Research 1987), and in the Geonics Limited instruction manuals for the EM38 ground conductivity meter (Geonics Limited 1992a), the EM61 high sensitivity metal detector (Geonics Limited 1998b), and the DL720 polycorder (Geonics Limited 1998a).

GEOPHYSICAL SURVEY METHODOLOGY

Initially, a metal detector sweep was made across the area. Based on the number of artifacts (approximately ten artifacts) recovered after the metal detector sweep of the western edge of the T1 terrace located at the western edge of the Sand Creek village site, a geophysical grid was established over this area. The cluster of artifacts suggested the potential for cultural features within the artifact concentration on the William Dawson property and on the adjacent August Kern property. The grid consisted of four 20 x 20 meter grids with overall dimensions of 40 meters by 40 meters. The grid was oriented to magnetic north (Figure 3). Wooden two-inch hubs were used as corner stakes for each 20 x 20 meter grid unit. Base lines of 20-meter long ropes were laid between the wooden hubs in an east-west orientation. The ropes were divided into 0.5 meter sections by alternating colored tape. This allowed the investigator to maintain the correct spacing for the acquisition of the data. In the north-south direction, the ropes were placed at meter intervals across each 20 x 20 meter grid unit. Geophysical data were collected along the north-south oriented grid ropes at 8 samples per meter for the magnetic survey, 2 samples per meter for the conductivity survey and 4 samples per meter for the metal detection survey. Data were also collected along each meter interval across the individual grid units.

The ground was covered in a sequence of one-meter traverses adjacent to one another (Geoscan Research 1987:43-48, 1993:5/1-5/7). The survey was conducted in a zig-zag fashion beginning at the southwest corner of each grid unit. The zig-zag method reduces the time required to conduct a survey by eliminating the return walk back to the southern starting point of the next transverse.

Upon completion of the area survey, the individual grid unit data files were downloaded into a laptop computer and processed. The data from each grid unit was stored in separate grid data files. The grid data files were combined into a composite data file for further processing and display. Shade, dot density, image, and trace line plots were generated in the evenings as the field work progressed. The data transfer for the magnetic data from the gradiometer to the laptop computer occurred in the field. Data from the conductivity and metal detection survey or at the office during the day or at the motel in the evening. Data analysis and interpretation can occur at any time once the data from the instruments have been transferred to a computer.

Magnetic Gradient Survey

A magnetic survey is a passive geophysical techniques used to measure the earth's total magnetic field at a point location. Its application to archeology results from the effects of magnetic materials on the earth's magnetic field. These anomalous conditions result from magnetic materials and minerals buried in the soil. Iron artifacts have a very strong effect on the local earth's magnetic field. Other cultural features which affect the local earth's magnetic field include fire hearths, soil disturbances (e.g., pits, mounds, wells, pithouses, dugouts, etc.), and geological strata (Clark 1996; Heimmer and De Vore 1995). Two types of magnetic surveys exist. One type is the total field survey while the other is the gradient survey. The total field survey uses a single magnetic sensor. The instrument is designed to measure the absolute total intensity of the total magnetic field. The type used in this survey is the magnetic gradient survey. The magnetometer has two magnetic sensors mounted in the vertical mode. This helps minimize the strong gradient influences and solar or diurnal effect on the survey data. It also provides for greater feature resolution and potentially provided for better classification of the magnetic anomalies. The sensor separation in the FM36 fluxgate gradiometer is approximately 0.5 meters. Due to the distance dependence of the sensors to the anomaly, the gradient or difference of the measurements between the two sensors helps define the buried material or object with increased resolution (Heimmer and De Vore 1995:11-20).

The magnetic gradient survey (Figure 4) was conducted with a Geoscan Research FM36 fluxgate gradiometer (Geoscan Research 1987). The gradiometer consists of a control unit that contains the electronics and memory. A handle connects the control unit to the vertical sensor tube that contains the two fluxgate magnetometer sensors. With a built-in data logger, the gradiometer provides fast and efficient survey data acquisition. Two readings are taken at each point along the survey traverse, one at the upper sensor and one at the lower sensor. The difference of gradient between the two is calculated and recorded in the instrument's memory.

A sample trigger (ST1) was connected to the front of the control unit of the fluxgate (Geoscan Research 1987:110-116). This trigger enables the gradiometer to collect and record data measurements at 1 m, 0.5 m, 0.25 m, and 0.125 m intervals. The gradiometer was configured to record data at a sampling interval of 0.125 meters or 8 samples per meter. The magnetic gradient data were recorded in nanotesla (nT) which is a unit of magnetic flux density (Sheriff 1973:148). A total of 3,200 data values were recorded per each 20 m x 20 m grid unit. A total of 12,800 data values were collected during the survey. The mean for the magnetic gradient data was -0.00555 nT with a standard deviation of 1.13076 nT. The minimum value was -15.43789 nT and the maximum value was 10.46154 nT.

The data were downloaded to a laptop computer and processed using the Geoscan Research GEOPLOT ver. 2.02 software (Walker and Somers 1995). Data from each individual grid unit were placed in its own grid data file. The grid data files were combined to form a composite file of all the data collected during the magnetic survey.

The creation of the composite file allowed for further processing of the magnetic gradient data. A zero mean of each transverse processed on the data set. This function sets the background mean of each traverse within the grid to zero. It is useful in removing the striping effects on the data in the traverse direction of a zig-zag fluxgate gradiometer survey. The function operates over the entire data set. Shade, dot density, and trace line plots were generated upon completion of the magnetic survey. The data were transferred in a XYZ data file for further processing and display in Golden Software's SURFER FOR WINDOWS program (Keckler 1997). In SURFER, the data were presented in a gray scale image plot (Figure 5) and a color image plot (Figure 6).

Electromagnetic Conductivity Survey

An electromagnetic conductivity (commonly referred to as a conductivity survey) was also conducted at the village site (Figure 7). The conductivity survey was conducted with a Geonics EM38 ground conductivity meter (Geonics Limited 1992). The instrument is light weight and approximately one meter in length. The transmitting and receiving coils are located at opposite ends of the meter. An electromagnetic field in induced into the ground through the transmitting coil. The receiving coil detects the response alteration (secondary electromagnetic field) in the primary electromagnetic field resulting from changes in the materials buried in the soil or soil disturbances from natural or cultural modifications to the soil. Thus the instrument has the ability to detect lateral changes on a rapid data acquisition, high resolution basis. In archeology, the instrument has been used to identify areas of compaction and excavation as well as buried metallic objects. It has the potential to identify cultural features that affect the water saturation in the soil (Clark 1996; Heimmer and De Vore 1995:35-41).

Digital meters are located on the top and side of the EM38 for the vertical and horizontal dipole measurements. The controls are located beside the vertical digital meter on top of the instrument. The controls include the range switch, the mode switch for setting the quadrature (Q/P) or conductivity, the in-phase (I/P) or magnetic susceptibility, and the battery check. Other switches include the Q/P zero control, the I/P coarse zero control, and the I/P fine zero control.

The meter was connected to the DL720 Polycorder for digital data acquisition (Geonics Limited 1998a). Data were collected manually with the push of the button located on the EM38 handle. The data stored in the polycorder were downloaded into the laptop computer at the end of the day. The apparent Conductivity data were recorded in units of millisiemens per meter (mS/m). The siemens is a unit of electrical conductivity that is the reciprocal of an ohm (Sheriff 1973197). Conductivity is the reciprocal of soil resistivity.

Data were collected at 0.5 meter intervals along 1 meter traverses. The survey was conducted in a zig-zag fashion beginning at the southwest corner of each 20 x 20 meter grid unit. The Em38 was used in the quadrature or conductivity phase. It provided an exploration depth of approximately 1.5 meters with its effective depth around 0.6 meters in the vertical dipole mode. A total of 800 data values were recorded per each 20

m x 20 m grid unit. A total of 3,200 data values were collected during the survey. The mean for the conductivity data was 33.96272 mS/m with a standard deviation of 6.50743 mS/m. The minimum value was 13.91600 mS/m and the maximum value was 61.79497 mS/m.

The data were downloaded to a laptop computer in the motel room following the day's field acquisition and processed using the DAT38 version 3.40 software (Geonics Limited 1997a). Data from each individual grid unit was placed in separate grid data file. The files were then converted from the DL polycorder files to the DAT38 file format. The individual EM38 grid data files were converted to SURFER data files for further processing in SURFER FOR WINDOWS (Keckler 1997). In SURFER, the data were presented in contour, surface, shade, and image plots. The SURFER data files were also formatted for input into the Geoscan Research software GEOPLOT (Walker and Somers 1995). The data files were stripped of the locational data columns leaving only the conductivity data values. The file was checked for the correct number of data values. In this case, with data collection every 0.5 meters at 1 meter intervals, there is a total of 800 data values per grid file. The data was imported into GEOPLOT where the grid files were combined to form a composite file. The creation of the composite file allowed for the further processing of the conductivity survey data. A bias, or numeric correction, was established for the data files that provided the same background level across the entire survey area. The composite was then further processed with the Edge Match function. This function is used to remove grid edge discontinuities. These discontinuities resulted from differences in the nulling and zero balancing operations before data collection and for instrument drift during data collection. Shade, dot density, and trace line plots were generated. The data was transferred in a XYZ data file for further processing and display in Golden Software's SURFER FOR WINDOWS program (Keckler 1997). In SURFER, the data were presented in a gray scale image plot (Figure 8) and a color image plot (Figure 9).

High Sensitivity Metal Detection Survey

In addition to the metal detector survey using commercially available metal detectors (Connor and Scott 1998), the present geophysical investigations of the Sand Creek village location utilized a Geonics EM61 high sensitivity metal detector (Figure 10). The instrument is a "High sensitivity high resolution time-domain metal detector which is used to detect both ferrous and non-ferrous metallic objects" (Geonics Limited 1998b:1). The instrument consists of a transmitter and two receiver coils. The transmitter generates a pulsed primary magnetic field that induces eddy currents in near surface or surface metallic objects. The decay of these eddy currents are measured by the two receiver coils and recorded and displayed by an integrated data logger as two channel information. The unit consists of a backpack with battery and processing electronics, the coil assembly, and digital data recorder (DL720 Polycorder). The present survey used the hand held unit (EM61-HH) with the wheel option for the sensor assembly (Geonics Limited 1998b:7-11). The coil assembly consists of a small set of coils attached to a wand that can be attached to a set of wheel are carried in the hands. More inline control is present when the wand with the sensors is set into the wheel assembly. Data acquisition is initiated by the odometer mounted inside the wheel assembly in the wheel

operation mode. The odometer is designed to trigger the recordation of the receiver coil data approximately every 0.2 meters. The two receiving sensors are identified as the top coil (T) and the bottom coil (B).

The meter was connected to the DL720 Polycorder for digital data acquisition (Geonics Limited 1998b). Data were collected automatically as the odometer on the wheel assembly triggered the polycorder at 0.196 m intervals (Geonics Limited 1998b:26). The data stored in the polycorder were downloaded into the laptop computer at the end of the day. The high sensitivity metal detection data were recorded in units of millivolts (mV).

Data acquisition was attempted at 0.25 meter intervals along 1 meter traverses. The survey was conducted in a zig-zag fashion beginning at the southwest corner of each 20 x 20 meter grid unit. A total of 1,600 data values were recorded per sensor for each 20 m x 20 m grid unit. A total of 6,400 data values were collected during the survey for each sensor. The mean for the top sensor data was 39.87806 mV with a standard deviation of 1.93394 mV. The minimum value was -27.02668 mV and the maximum value was 50.27815 mV. The mean for the bottom sensor data was 19.98458 mV with a standard deviation of 1.05560 mV. The minimum value was 3.79044 mV and the maximum value was 32.03297 mV.

The data were downloaded to a laptop computer in the motel room following the day's field acquisition and processed using the DAT61 version 1.70 software (Geonics Limited 1997b). Data from each individual grid unit was placed in separate grid data file. The files were then converted from the DL polycorder files to the DAT61 file format. The individual EM61 grid data files were converted to SURFER data files for further processing in SURFER FOR WINDOWS (Keckler 1997). In SURFER, the data were presented in contour, surface, shade, and image plots. The SURFER data files were also formatted for input into the Geoscan Research software GEOPLOT (Walker and Somers 1995). The data files were stripped of the locational data columns leaving only the metal detection data values. Two files were created one for the top sensor data and one for the bottom sensor data. These files were checked for the correct number of data values. In this case, with data collection every 0.25 meters at 1 meter intervals, there is a total of 1,600 data values per grid file. The data was imported into GEOPLOT where the grid files were combined to form a composite file. The creation of the composite file allowed for the further processing of the conductivity survey data. A bias, or numeric correction, was established for the data files that provided the same background level across the entire survey area. The composite was then further processed with the Edge Match function. This function is used to remove grid edge discontinuities. These discontinuities resulted from differences in the nulling and zero balancing operations before data collection and for instrument drift during data collection. Shade, dot density, and trace line plots were generated. The data was transferred in a XYZ data file for further processing and display in Golden Software's SURFER FOR WINDOWS program (Keckler 1997). In SURFER, the data were presented in top and bottom gray scale image plots (Figure 11 and 12) and top and bottom color image plots (Figure 13 and 14).

INTERPRETATIONS AND CONCLUSIONS

The magnetic gradient data from the 40 meter square geophysical grid contained few magnetic anomalies (Figure 15). Three major anomalous areas are located at N7/E14, N10/E26, and N29/E24. Three smaller magnetic anomalies are located at N40/E17, N40/E18, and N35/E20. Two areas along the N200 line in the vicinity of E15 and E18 reflect some edge matching problems with the northwest and southwest quadrants of the geophysical grid. Given the recovery of iron artifacts from the site during the metal detector investigations, it is probably safe to say that the six anomalies probably represent iron artifacts dating to the 1864 massacre.

The conductivity data appear to represent natural changes in the terrace. Areas of high conductivity appear at the north central portion of the area, as well as along much of the southern edge. A third area of high conductivity is found near the middle portion of the west edge of the project area. Two areas within the grid appear to be associated with the magnetic gradient anomalies. These are located at N7/E14 and N29/E24. These two low conductivity anomalies are probably the same two magnetic anomalies in the gradient data set.

The high sensitivity metal detection data provide indications that there are several metallic objects within the geophysical grid. The top coil data indicate a number of targets throughout the grid; however, those along the N20 line appear to represent an edge matching problem that resulted during the data acquisition phase. Two of the three large magnetic anomalies are present in the top coil data of the EM61; however, they are not the same two present in the EM38 conductivity data. These are located at N7/E14 and N10/E26. The bottom coil data suggests that there are four to five times as many anomalous objects or targets. Again, the edge matching problem along N20 is visible. The two coil system is very useful in recognition of shallow objects from deeper ones. The amplitude of response is highly dependent upon the distance between the coil assembly and target object. Often smaller near surface objects will produce a response orders of magnitude higher than larger objects buried at greater depths (Geonics Limited 1998b:44,46). This masking effect can be reduced by using the data from the two coils and process them in a differential mode. "...output from channel B(2) subtracted from channel T(1). Channel T(1) represents data from the top receiver coil, whereas channel B(2) is data from the coil closer to the ground. The calculation is automatically preformed by EM61 DAT61 computer program" (Geonics Limited 1998b:44,46). This is the most common way to interpret the EM61 is to use the channel B92) data and the differential channel data:

> The differential channel is calculated by the program in the following way:
>
> **D = k * CHT(1) - CHB(2)**
>
> where: D is differential output in mV
> CHT(1) is output from top coil in mV
> CHB(2) is output from bottom coil in mV
> K is depth coefficient normally set to 1

> It is possible to vary **k**, and adjust the depth at which the response will be suppressed the most. If **k** is selected to be 1, the response from targets right below the surface will be reduced the most. If the coefficient **k** is made smaller than 1, the deeper target will be suppressed more than the shallow targets. In this case surface anomalies will have negative response in the differential channel.
>
> It should be noted that the degree of cancellation will be effected by size, shape and depth of targets. The response from the targets with small dimensions shaped like balls, shales or small plate-like targets parallel with the ground, is possible to reduce much more than response from larger 3 dimensional targets (Geonics Limited 1998b:46).

Figure 16 represents the anomalous areas after the receiver data from the top and bottom coils have been differentially corrected with a **k** value of 1.

Although it would archeological excavation to identify the nature of the geophysical anomalies identified in the magnetic gradient, conductivity, and high sensitivity metal detection data sets; it is apparent that the methods are appropriate for the area of the village location. The small area extent of the geophysical investigations have provided positive data concerning the presence of buried archeological material, which some objects have already been identified and collected during the metal detector survey of the Sand Creek Massacre Site. Should the site be placed under governmental or tribal control, it is recommend that geophysical investigations be considered as an appropriate means of evaluating the site extent and integrity.

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FIGURES

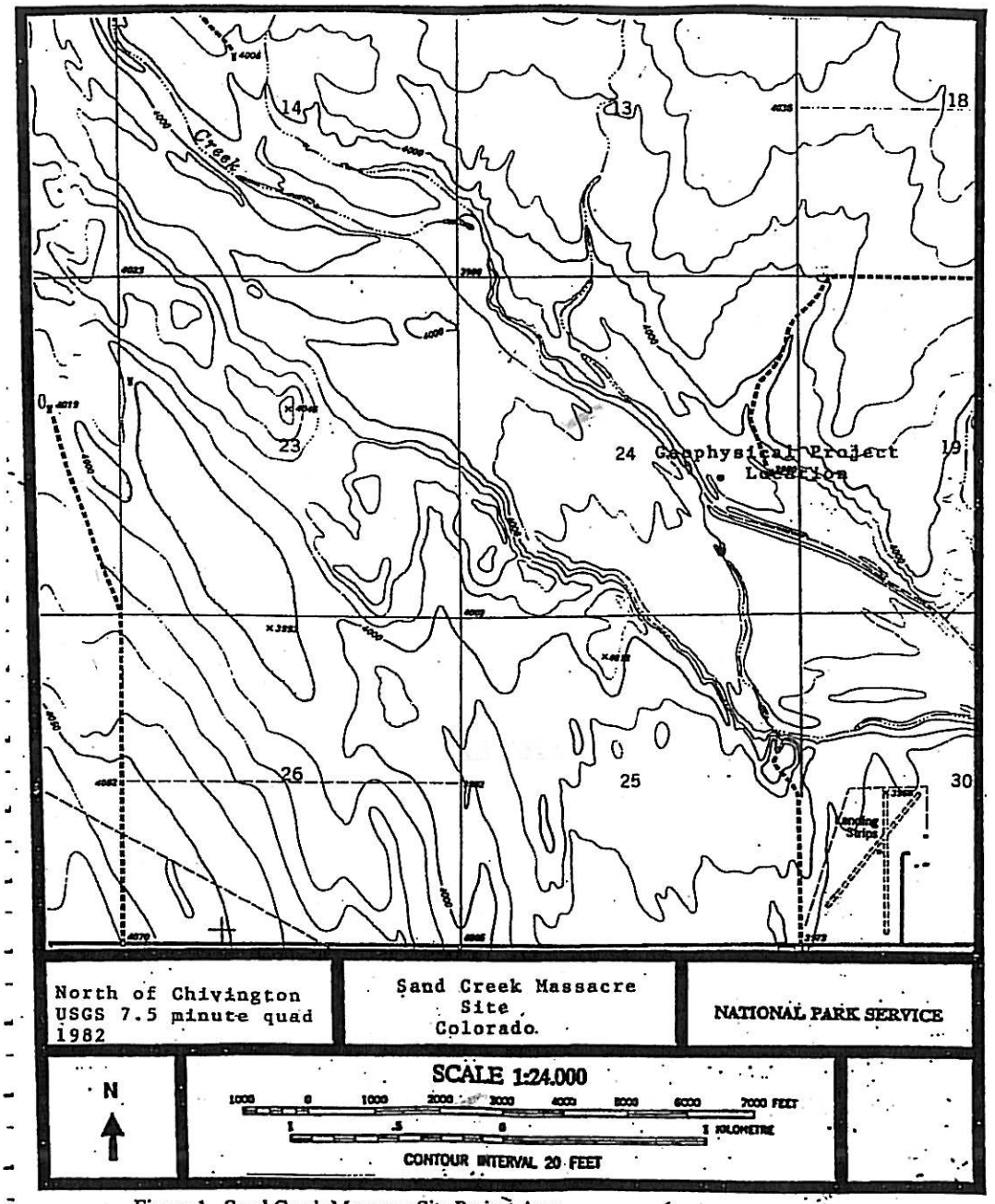

Figure 1. Sand Creek Massacre Site Project Area.

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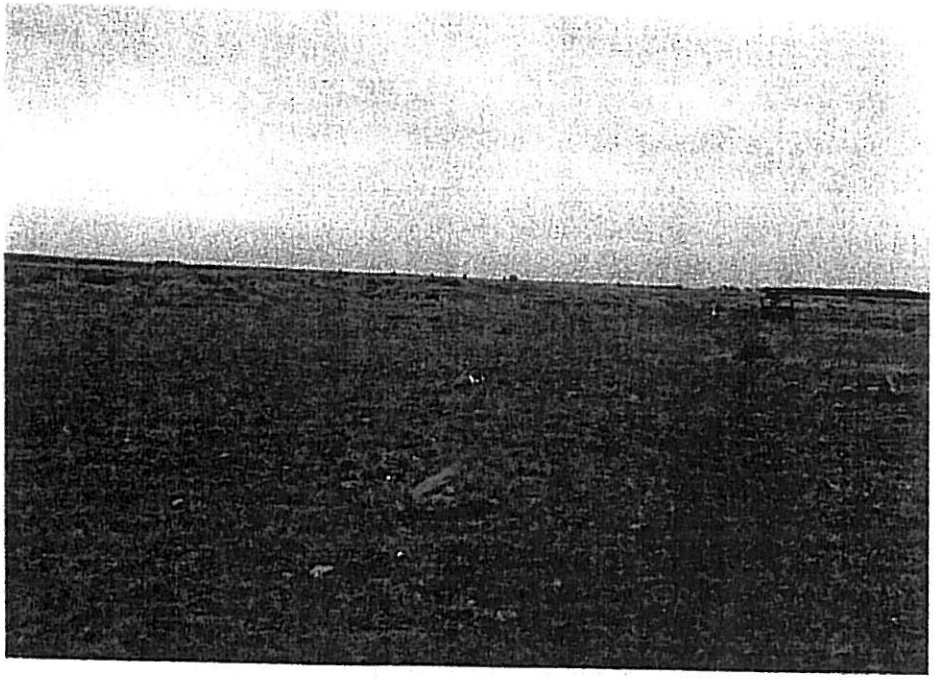

Figure 2. Sand Creek Village Location (view to the east).

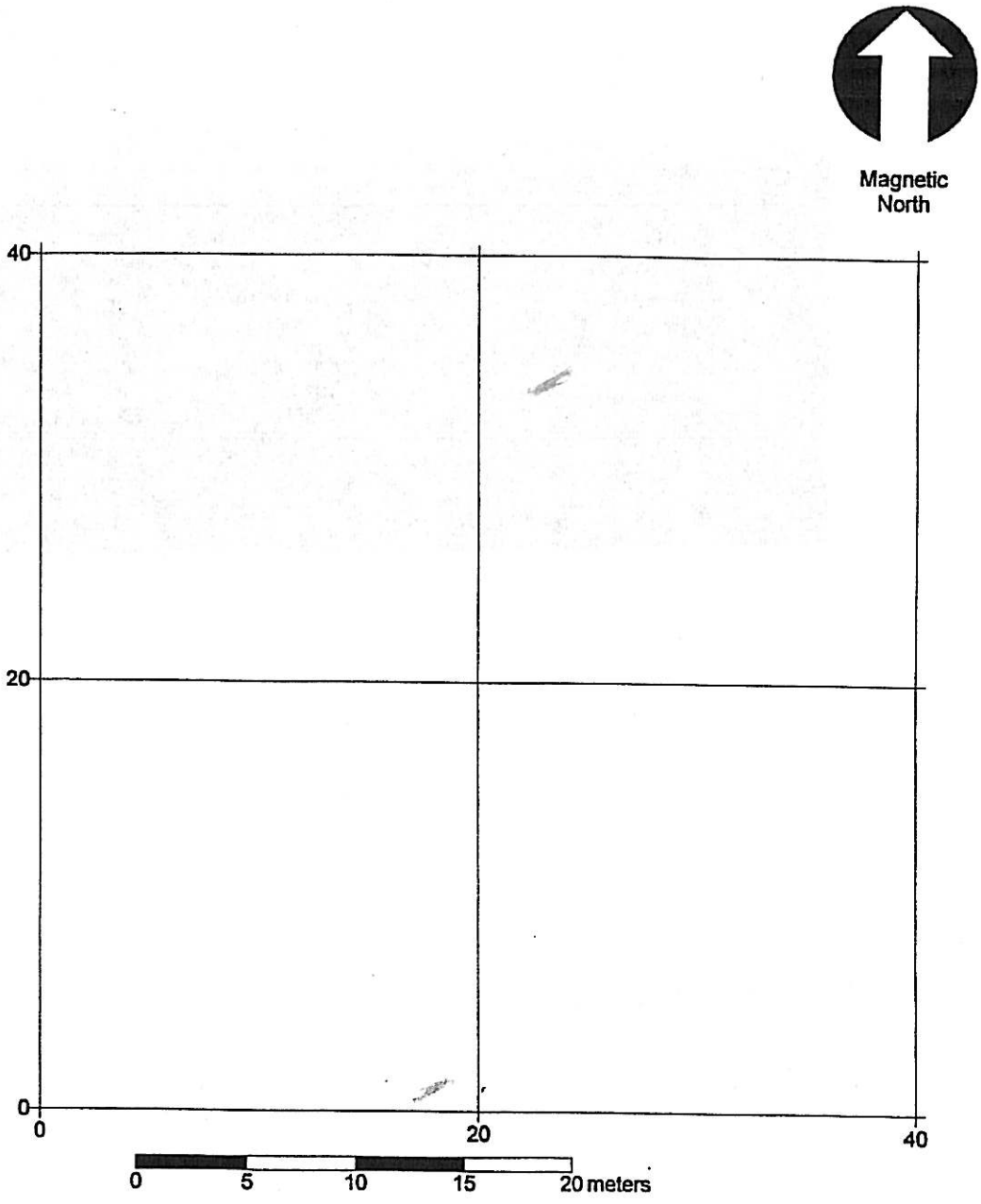

Figure 3. Geophysical Grid at the Sand Creek Village Location.

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Figure 4. Magnetic Gradient Survey with Geoscan Research FM36 Fluxgate Gradiometer (view to the northeast).

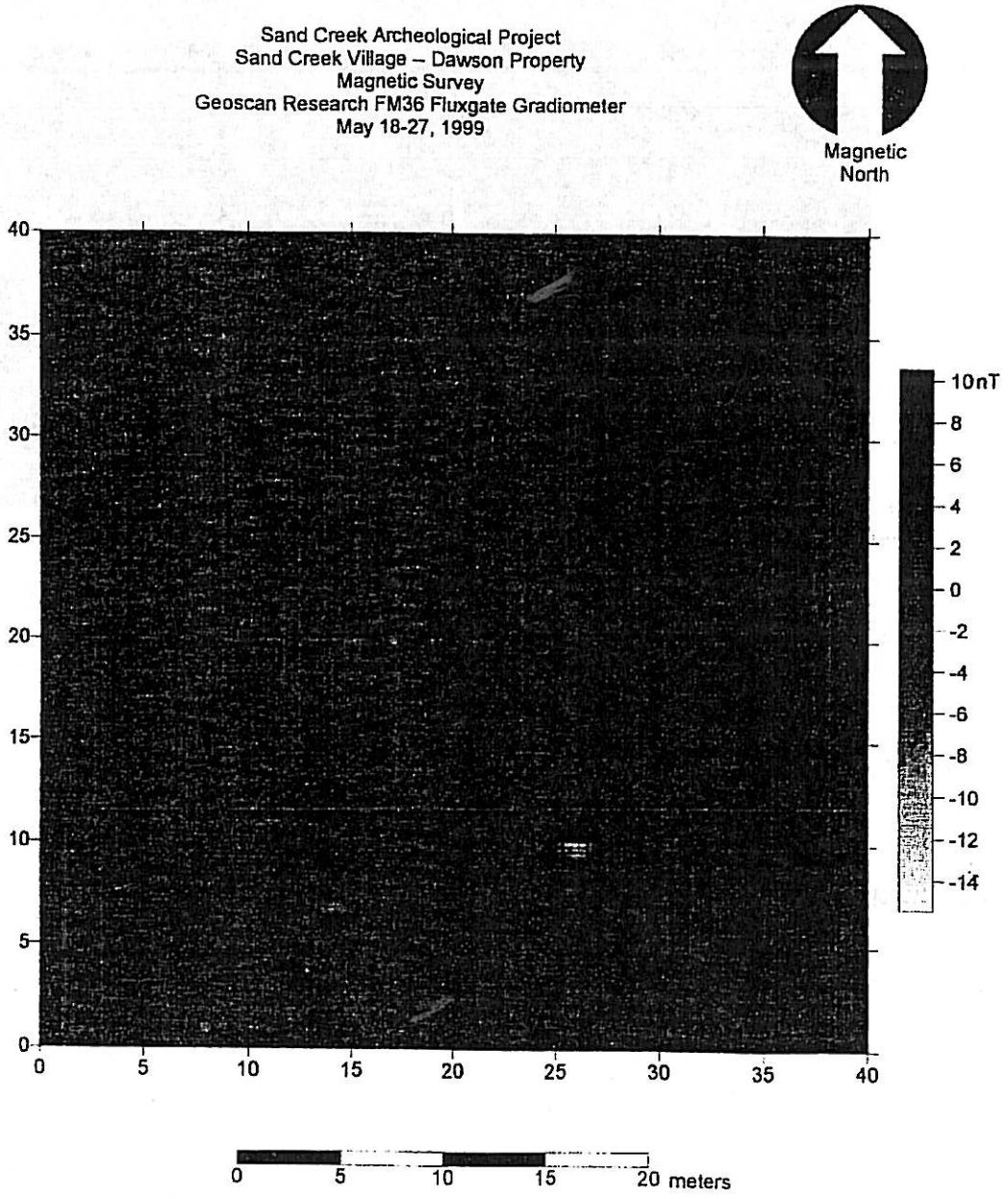

Figure 5 Gray Scale Image Plot of Magnetic Gradient Data.

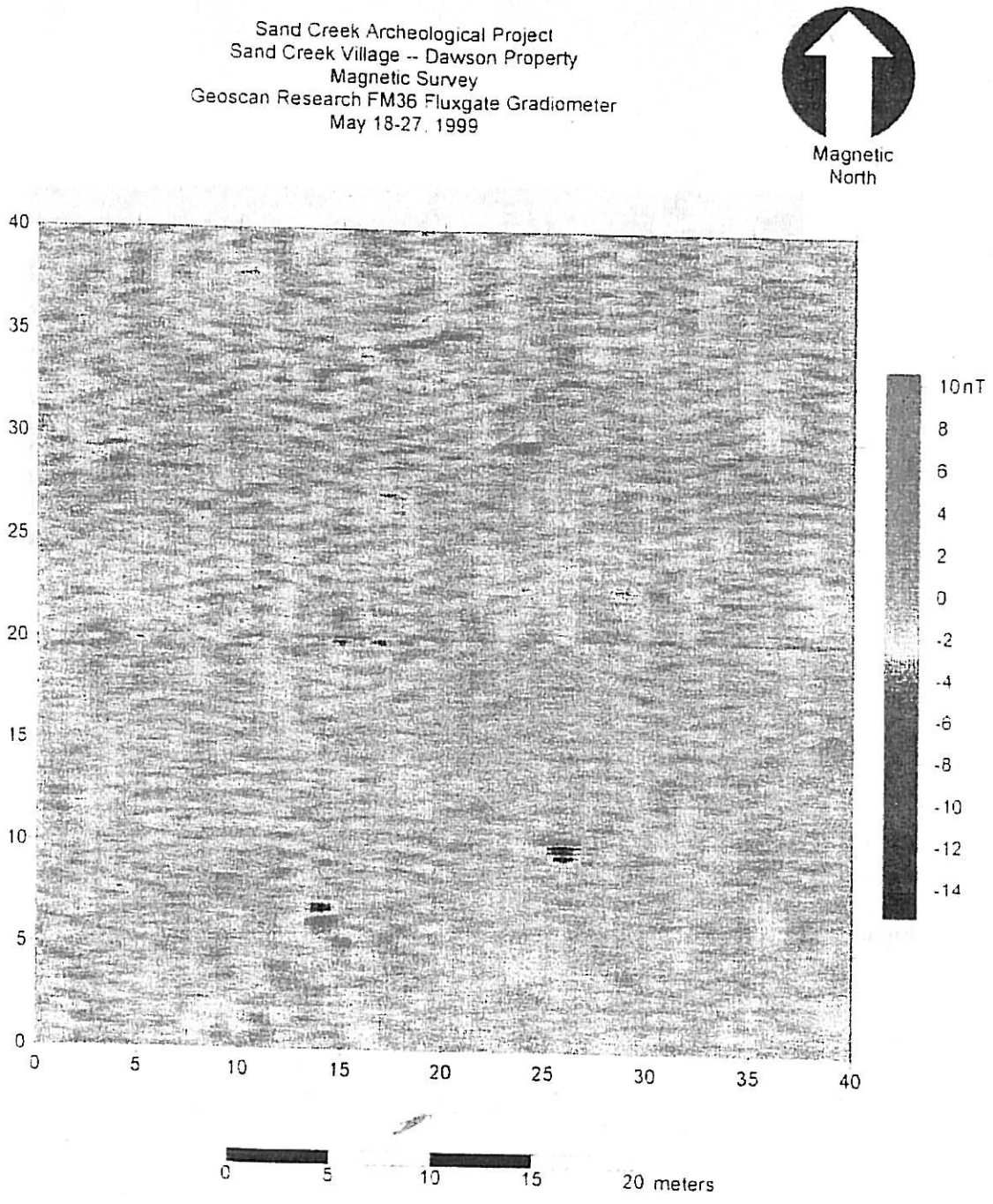

Figure 6 Color Scale Image Plot of Magnetic Gradient Data

Figure 7. Geonics EM38 Ground Conductivity Meter (view to the northeast).

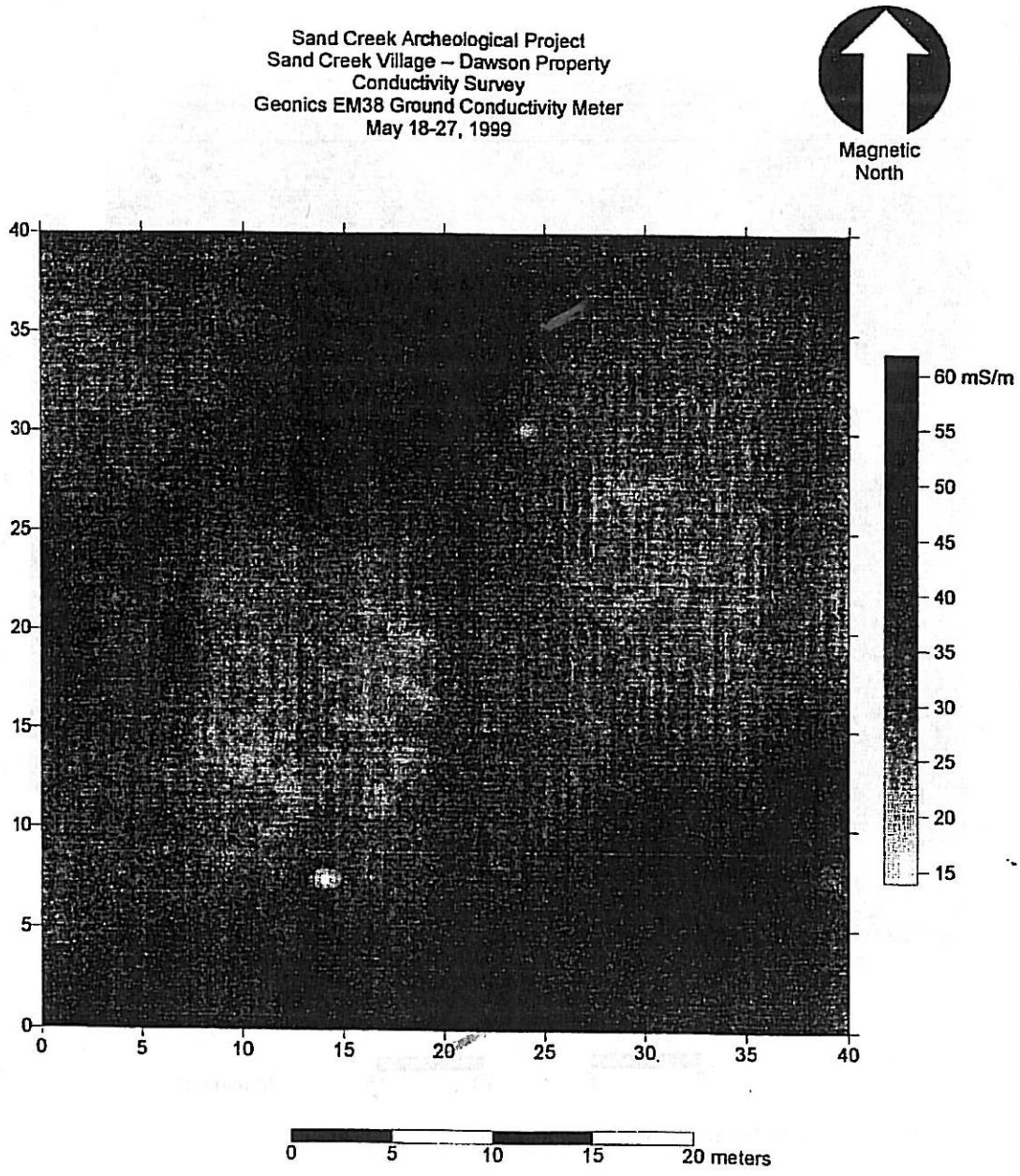

Figure 8. Gray Scale Image Plot of Conductivity Data.

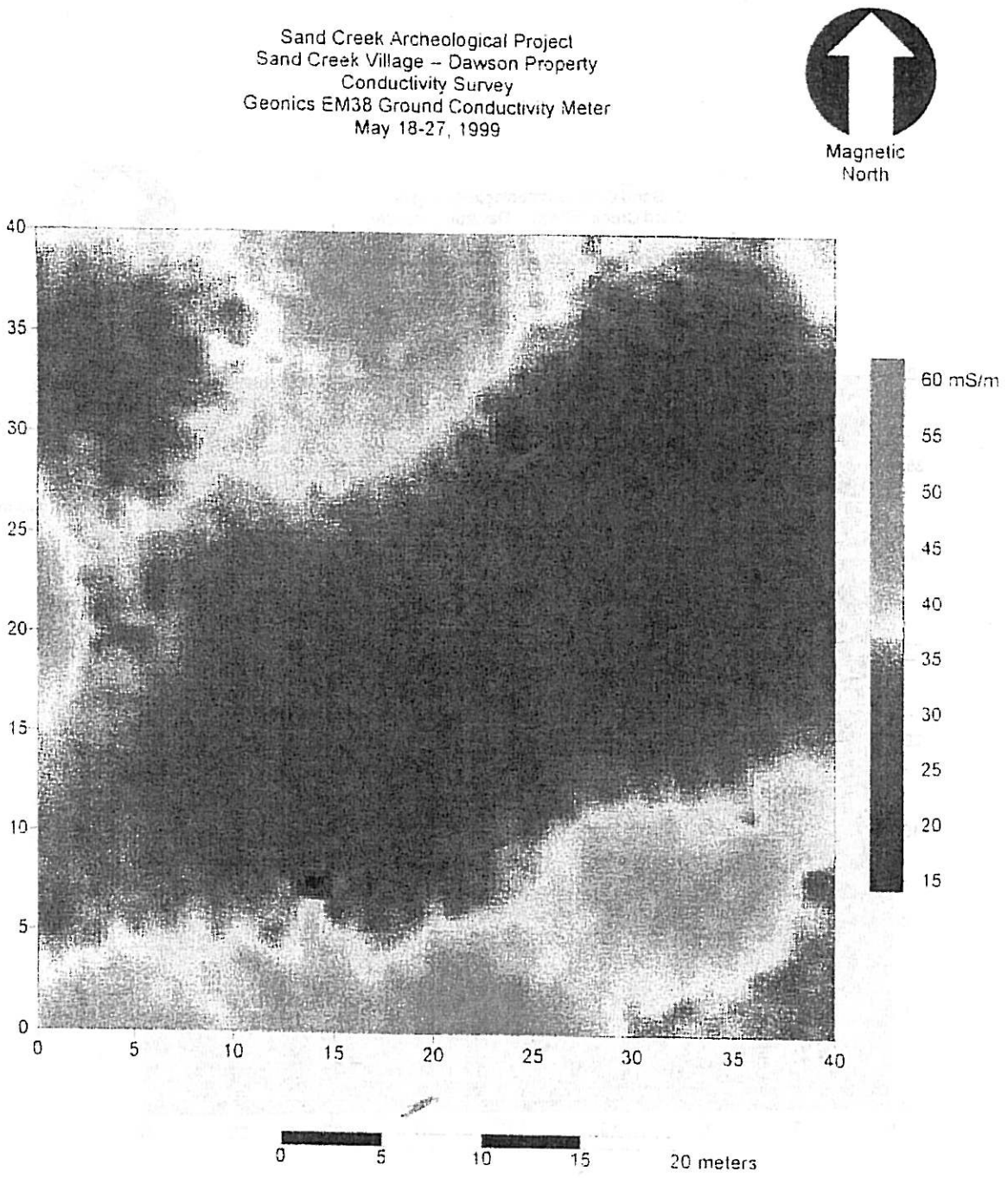

Figure 9 Color Scale Image Plot of Conductivity Data

Figure 10. Geonics EM61 High Sensitivity Metal Detector (view to the southwest).

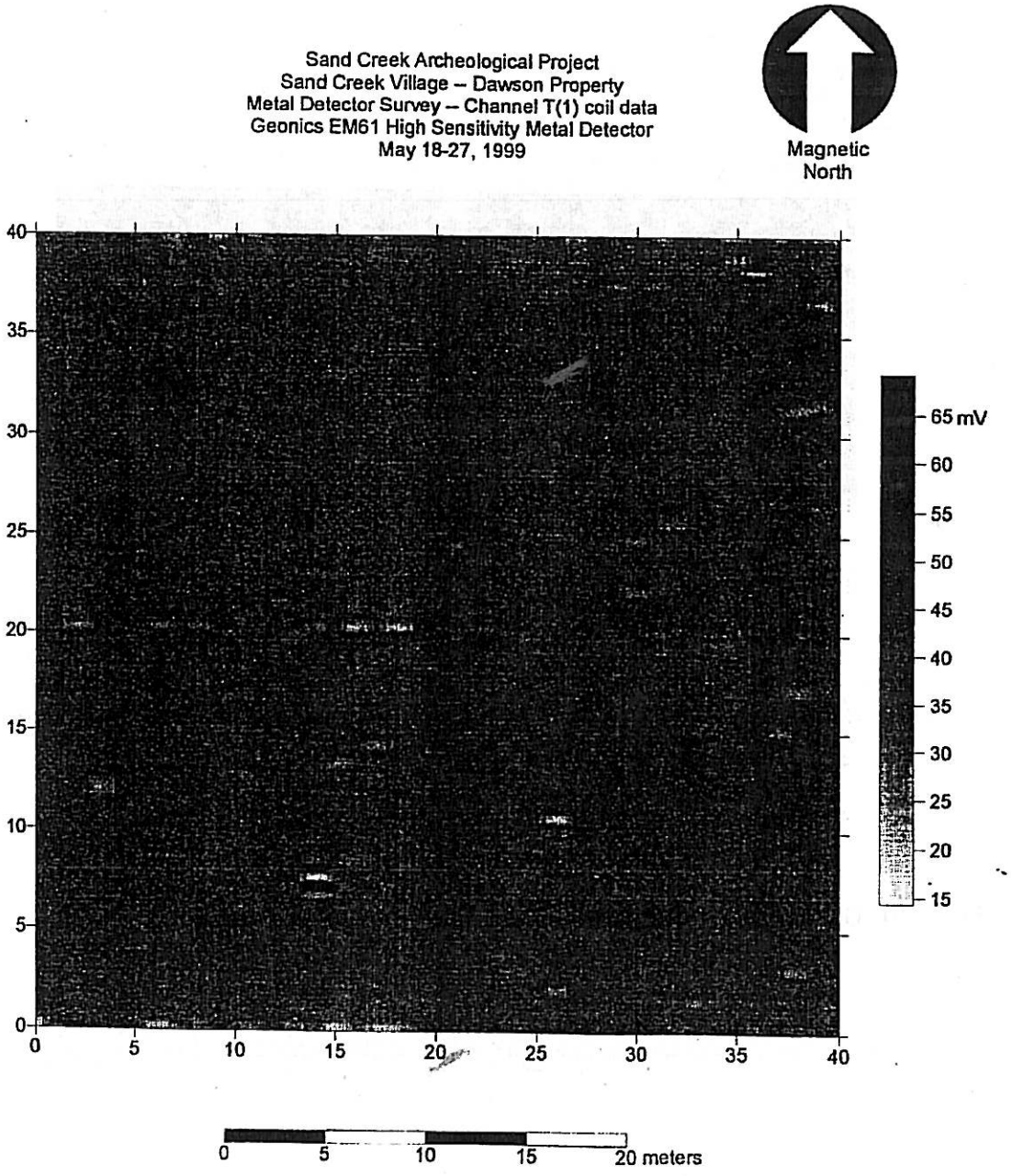

Figure 11. Gray Scale Image Plot of the Channel T(1)/Top Sensor Data.

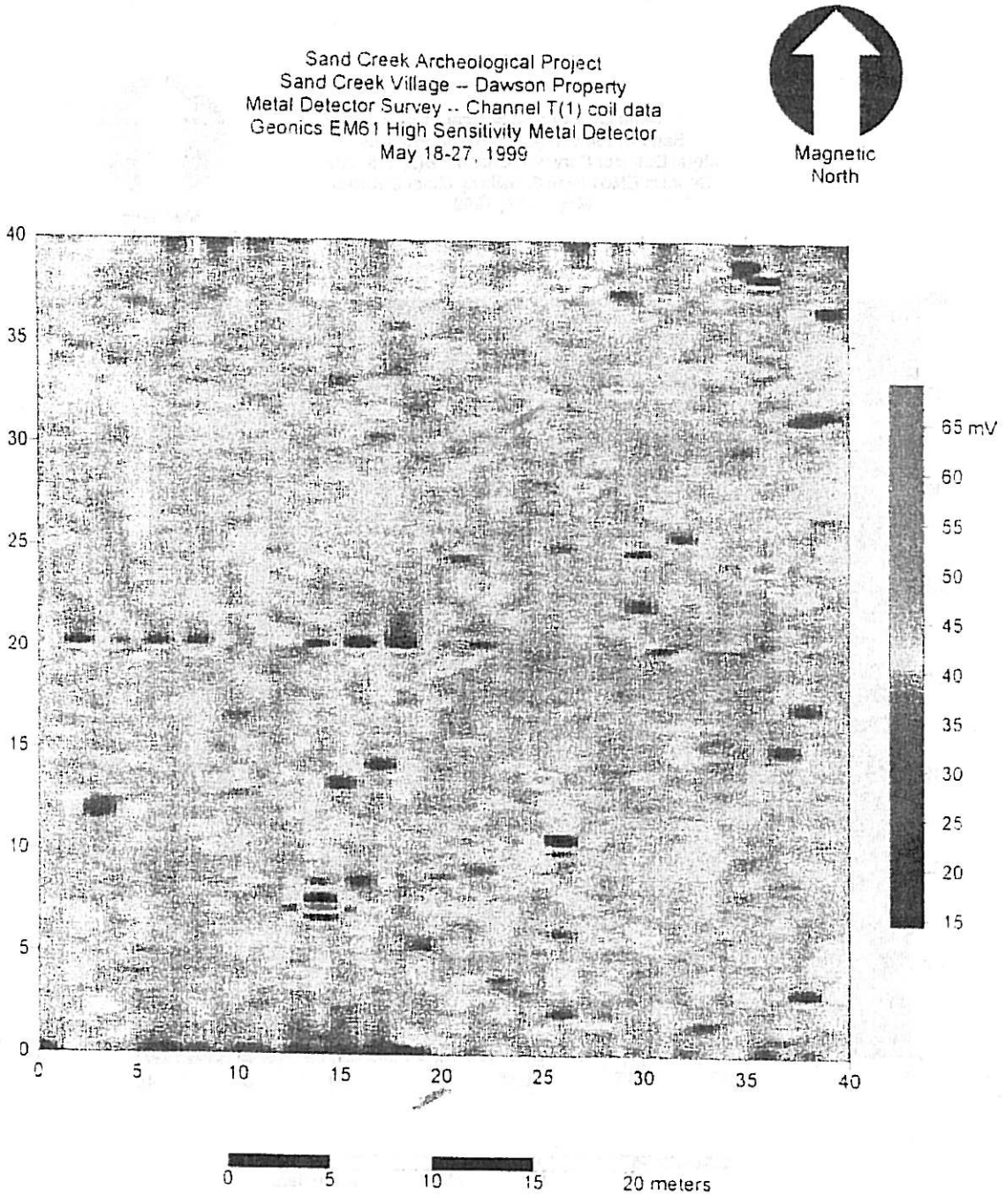

Figure 12 Color Scale Image Plot of the Channel T(1)/Top Sensor Data

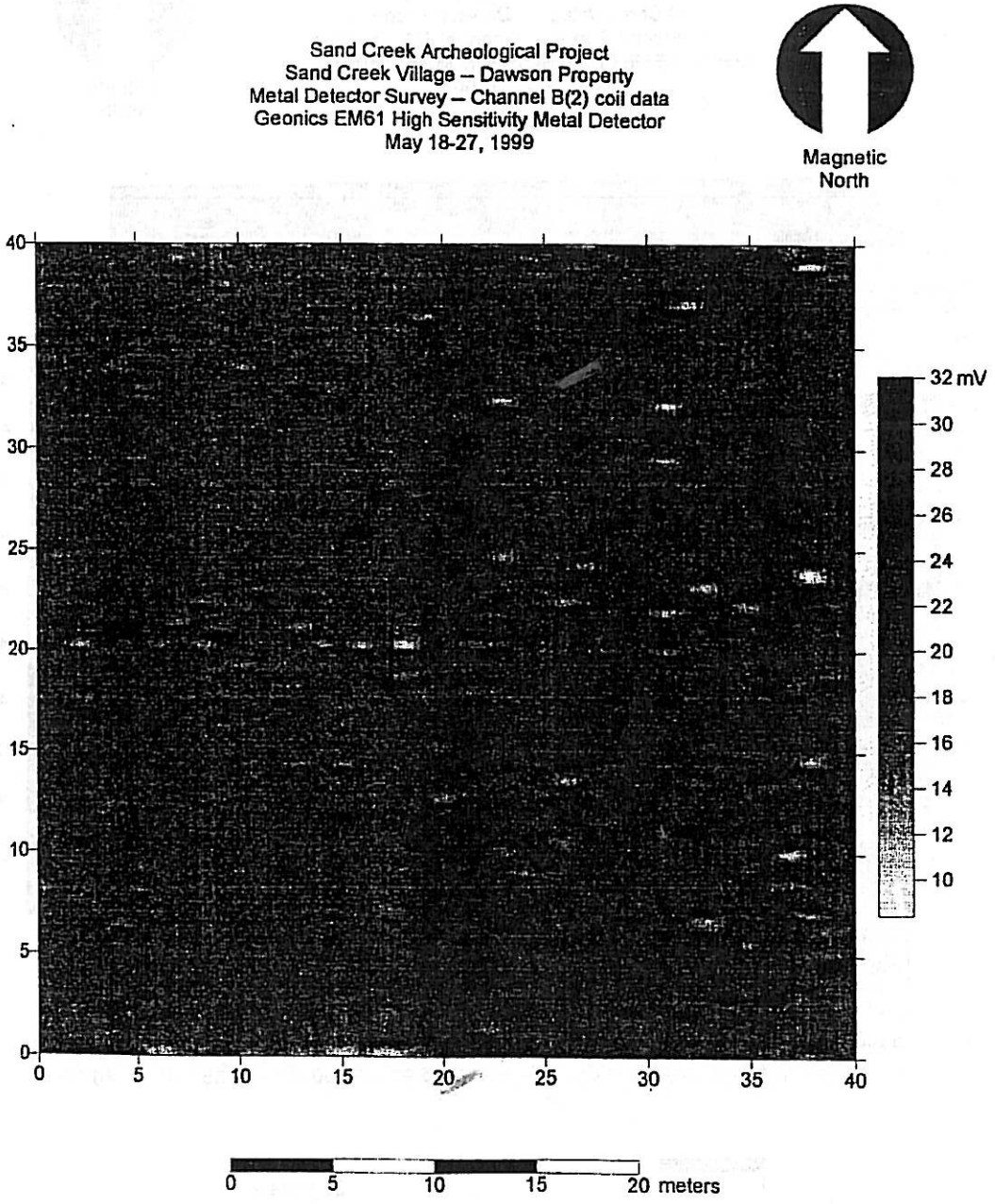

Figure 13. Gray Scale Image Plot of the Channel B(2)/Bottom Sensor Data.

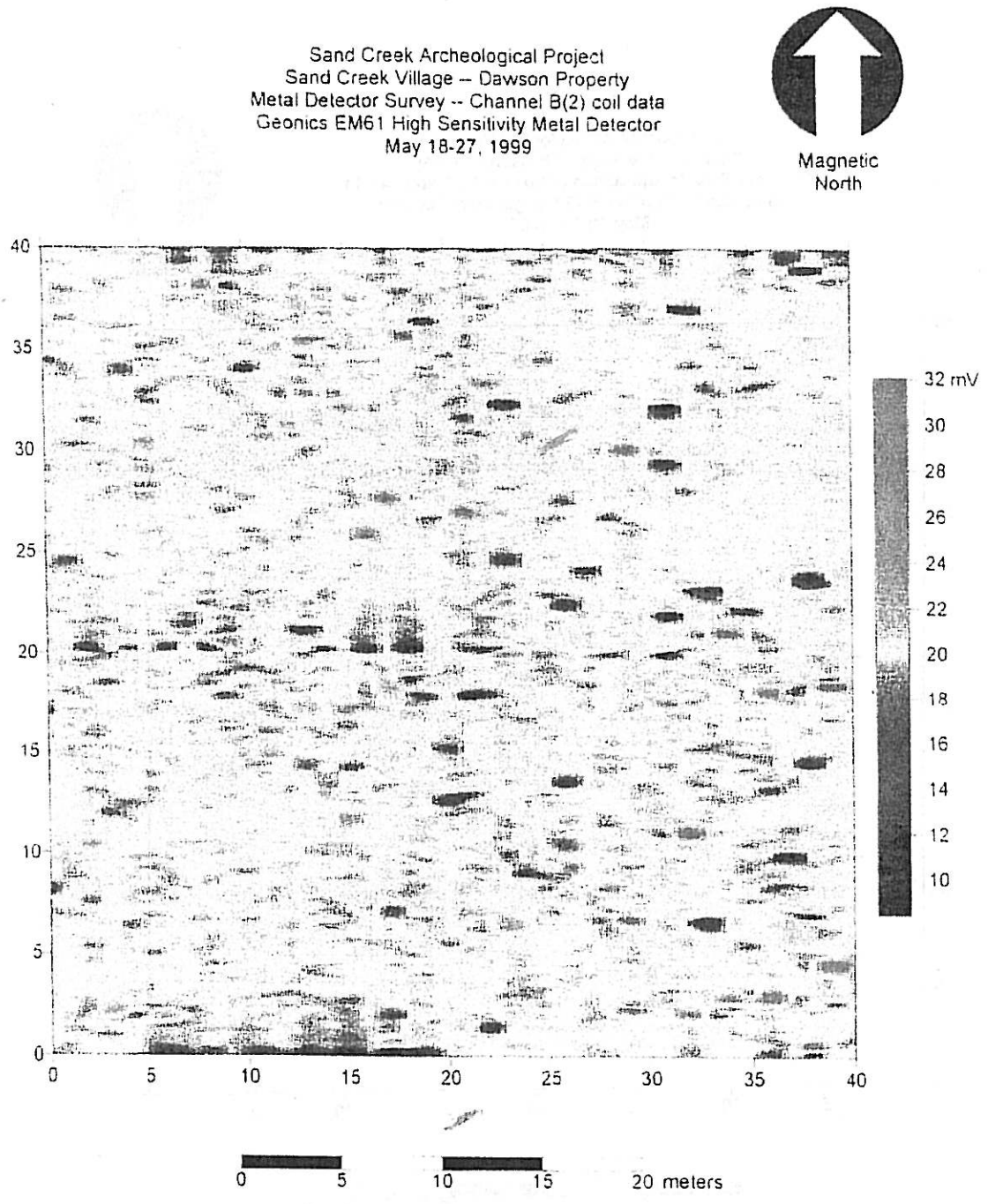

Figure 14 Color Scale Image Plot of the Channel B(2)/Bottom Sensor Data

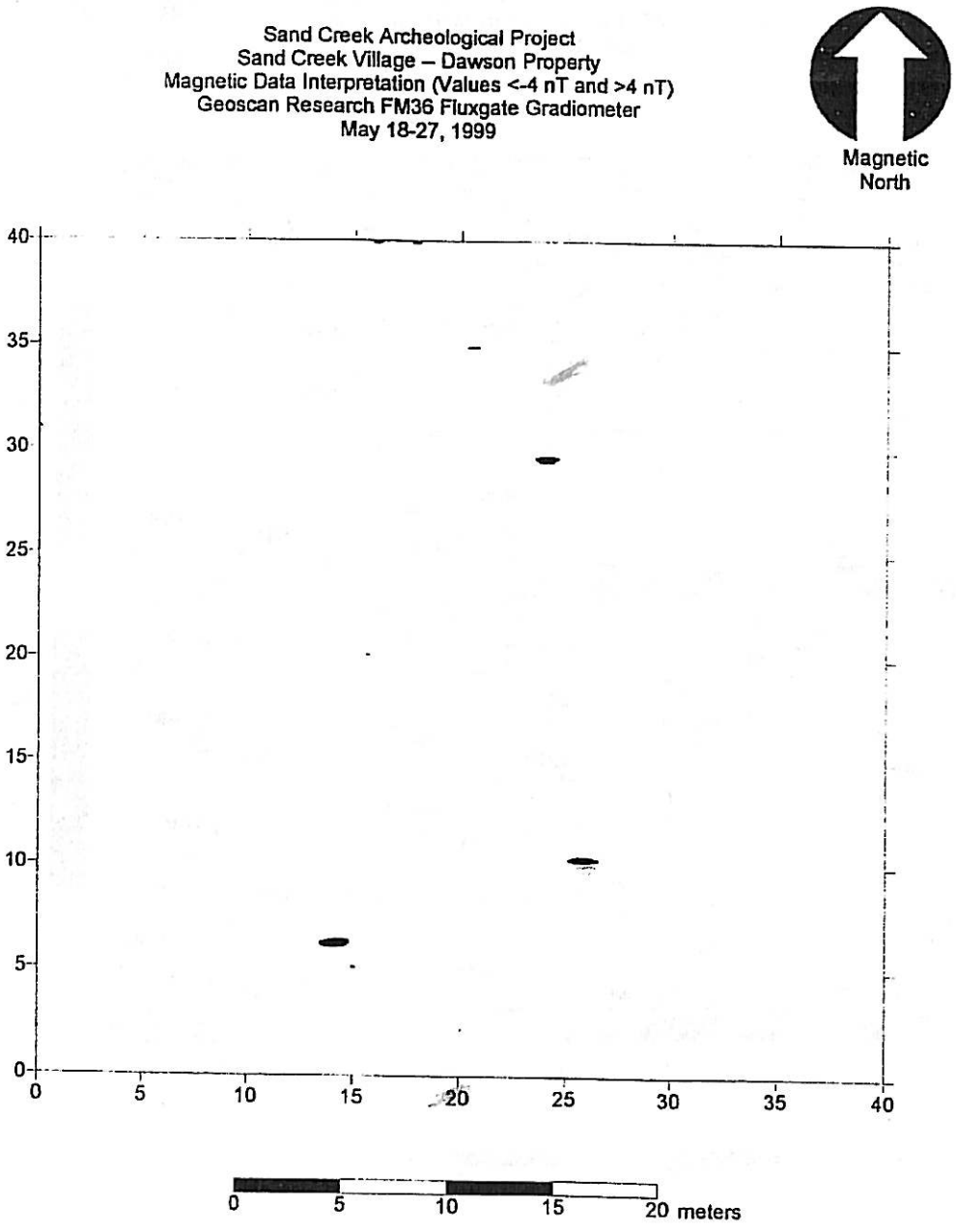

Figure 15. Image Plot of Magnetic Gradient Data Less Than -4 nT and Larger Than 4 nT.

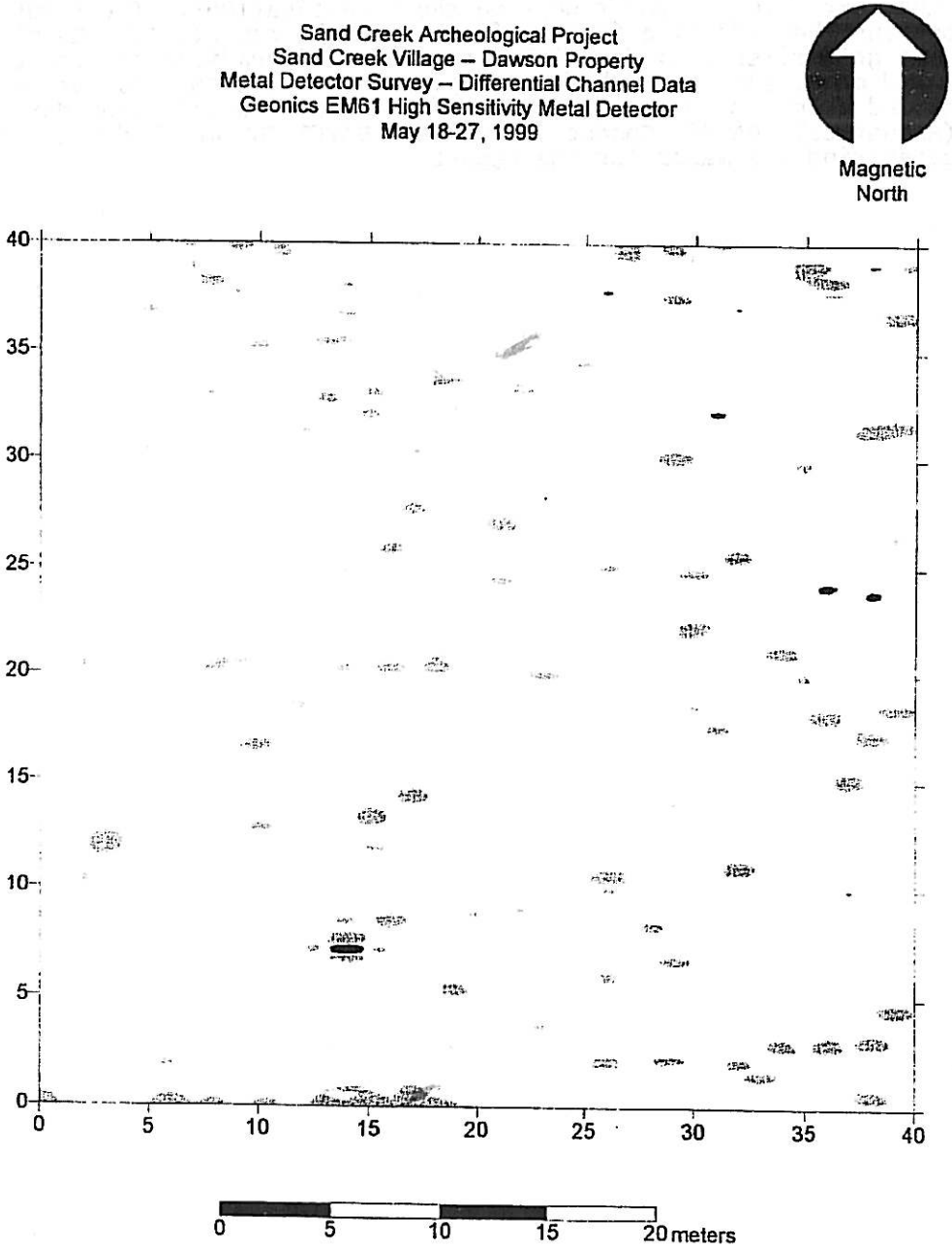

Figure 16. Image Plot of Differential Channel Data from EM61.

readme

The folders on this CD contain the geophysical data collected at the Sand Creek massacre Site during the investigations in 1999. The Word97 folder contains the text file for the report on the investigations. The Illustrations folder contains the tiff file fort he figures in the report. The Geoplot folder contains the grid files (raw data filed for the FM36 gradiometer, the comp files of the processed data, and the mesh file templates. In the EM61 folder are the raw data files and processed DAT61 files. Surfer7 folder contains the data files from GEOPLOT (Magnetics), DAT38 (Conductivity), and DAT61 (HD metal detection) that were used in generating the mapps for the report.

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GEOARCHAEOLOGICAL ASSESSMENT OF THE SAND CREEK MASSACRE SITE KIOWA COUNTY, COLORADO

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18 OCTOBER 1999

ABSTRACT

Geoarchaeological and geomorphological investigations at the four possible 1864 Sand Creek Massacre localities in Kiowa County, Colorado reveal that the study area is dominated by Quaternary alluvial and eolian landforms. We identified five major landforms or terrain types. These include the modern floodplain (T0), alluvial terraces T1, T2, T3, and an eolian-capped bedrock bluff. Terrace boundaries are discrete and partially masked by discontinuous eolian sands. The National Park Service found a probable massacre-age village site on the T1 and T2 terraces on a segment of the Dawson property. Overall, the core samples reveal minimal subsurface disturbance. Relative age-dating and depositional histories throughout the study area suggest that the eolian deposits on the T1, T2, T3, and bluff have the potential to yield Sand Creek Massacre-period cultural materials. Alluvial members of the T1 and T2 are also young enough to yield 1864-period materials. However, radiocarbon assay of organic paleosols buried at 23 cm below surface in the T1, and 97 cm in the T2 sediments at the Dawson Locality #3 show that the recent alluvium is relatively shallow.

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INTRODUCTION

Geoarchaeological investigations of the Dawson and Bowen properties, Kiowa County, Colorado, were undertaken to assist the National Park Service and the Cheyenne and Arapaho tribes in assessing four possible locations of the 1864 Sand Creek Massacre (Figure 1). Research was designed to determine if undisturbed geological deposits from the 1864 period were present, establish their depth below the surface, and assess the nature of post-1864 geologic and human disturbance. On May 20, 1999, a team of National Park Service and tribal representatives located 1864-period artifacts on a segment of the Dawson property. This paper presents the results of our geoarchaeological investigations of the Dawson and Bowen properties.

OBJECTIVES

The primary objective of this geoarchaeological investigation was to determine if the Dawson or Bowen properties had the potential to yield *in situ* evidence of the 1864 Sand Creek Massacre. Initially, we examined subsurface stratigraphic records to assess if undisturbed sediments were present. We then attempted to evaluate the extent of disturbance resulting from post-1864 agriculture, eolian deflation, and Big Sandy Creek flooding.

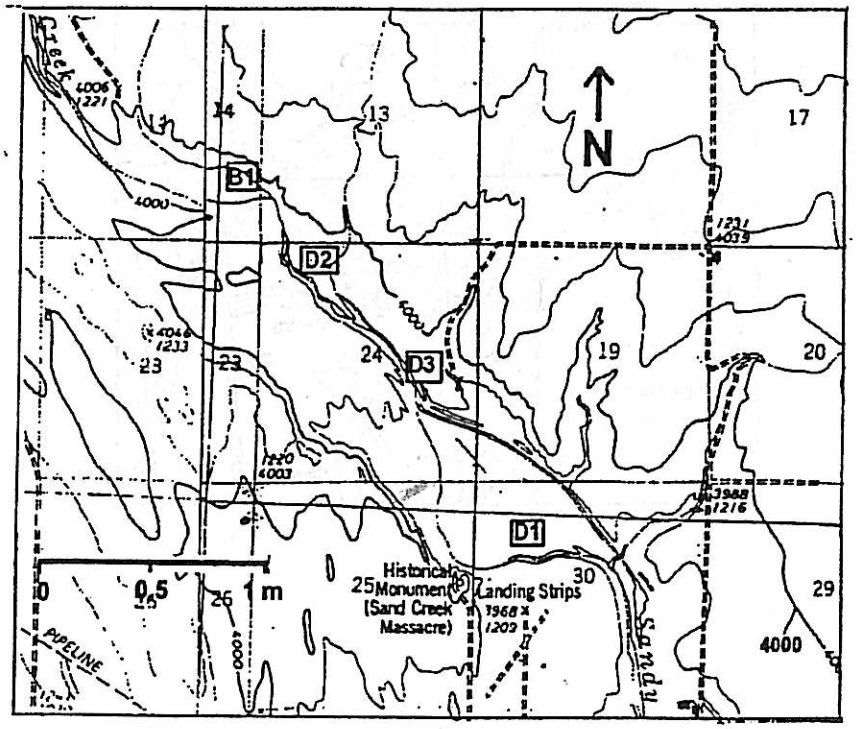

Figure 1. Map showing the four study areas.

METHODS

LaRamie Soils Service conducted a geoarchaeological reconnaissance of the Dawson property on August 26, 1998. The objective of the reconnaissance was to identify and delineate the types of landforms in the study area (McFaul 1986; McFaul et al. 1994; Haynes et al. 1997). Verification of reconnaissance results was made using pedestrian traverses across the property (Soil Survey Staff 1951). This process was also aided by the use of regional soil-morphological data (Mandel 1992), geologic maps (Coffin 1967), soil surveys (Anderson et al. 1981), and aerial archaeological research (Baker 1998). Mr. and Mrs. Dawson provided insight into historic use of these terrains and Big Sandy Creek flooding.

Between December 15-18, 1998, LaRamie Soils Service conducted a subsurface core sampling program at the Dawson Locality #1 at the South Dawson Bend (Figure 1). A total of 27 core localities were systematically sampled using a Giddings Soil Exploration device (Figure 2). On April 19-22, May 17-20, and August 10, 1999 LaRamie Soils Service conducted a second core sampling program at three additional locations on the Dawson and Bowen properties. During this time, 37 more core samples were collected. Samples were described following standard geologic and pedologic procedures (Birkeland 1984; Folk 1980; Krumbein and Sloss 1963; Soil Survey Staff 1951).

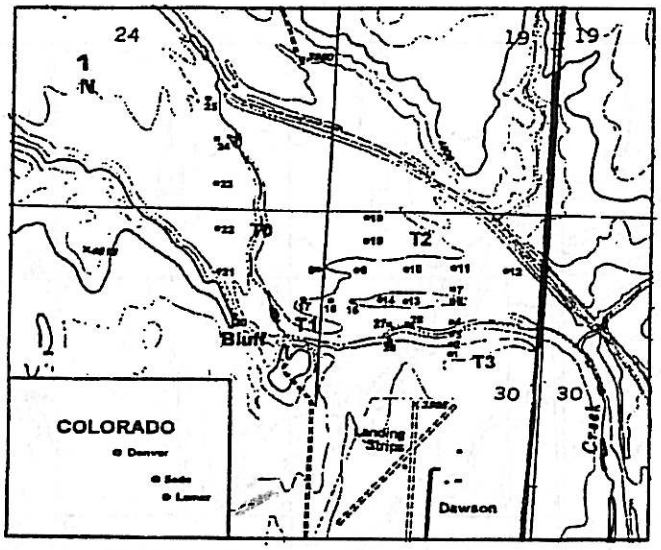

Figure 2. Map showing the December 1998 core localities at the Dawson Locality #1.

Core descriptions (Appendix A) were then compared to refine landform characteristics, depositional histories, soil development, and relative ages. Evaluations of soil development were used to approximate the relative ages of landforms and deposits. Two organic-rich samples were collected and sent to Beta Analytic, Inc. for radiocarbon assay (NPS #1443PX71209064, modification #2). The position of each core locality was determined using a Lightweight Global Positioning System Receiver (PLGR) or a Sokkia Total Station.

RESULTS

Cultural materials were not recovered in any of the core samples. The properties of the soils and sediments in each terrain group, their relative age, and their potential to yield *in situ* 1864-period artifacts are presented in the following section.

Landforms

The sampled segments of the Dawson and Bowen properties are dominated by Quaternary alluvial and eolian sediments. The Dawson and Bowen study areas contain five major landforms or terrain types. Numbered from youngest (T0) to oldest (T3) the landscape includes the modern floodplain T0, and alluvial terraces T1, T2, T3 (Figure 3). An eolian-capped bedrock bluff is also present. The alluvial terraces form a step-like sequence that represents abandoned floodplains (Figure 4). Within the study area, the T1 is 0.5 m above the floodplain, the T2 is 1.0 m above the floodplain, and the T3 is 1.5 m above the floodplain. By identifying when floodplain abandonment occurred, we assigned ages to the specific terraces, and subsequently assessed their potential to yield buried 1864-period artifacts. Terraces in the study are identified by the relative elevation of their tread height above the modern floodplain, degrees of soil development, and geologic characteristics.

Boundaries of the individual terraces are discrete and partially masked by discontinuous eolian sand. Similarity in eolian sand deposits and soil development suggests that this masking is the dominant post-Massacre depositional process throughout the study area. In general, the eolian sands are medium to coarse-grained, and well-sorted. The alluvial deposits exhibit coarse to very coarse, poorly to moderately-sorted, sands. Due to the relatively gentle nature of eolian deposition and the age of these sediments , there is high probability they can yield *in situ* 1864-period artifacts.

Dawson Locality #1

Dawson Locality #1 is at the South Dawson Bend of Big Sandy Creek (Figure 1; Sect 30, T17S R45W). In December 1998, LaRamie Soils Service core sampled 27 localities. In April 1999, three additional localities were cored for radiocarbon samples. All of the five landforms noted in the reconnaissance are present at Dawson Locality #1.

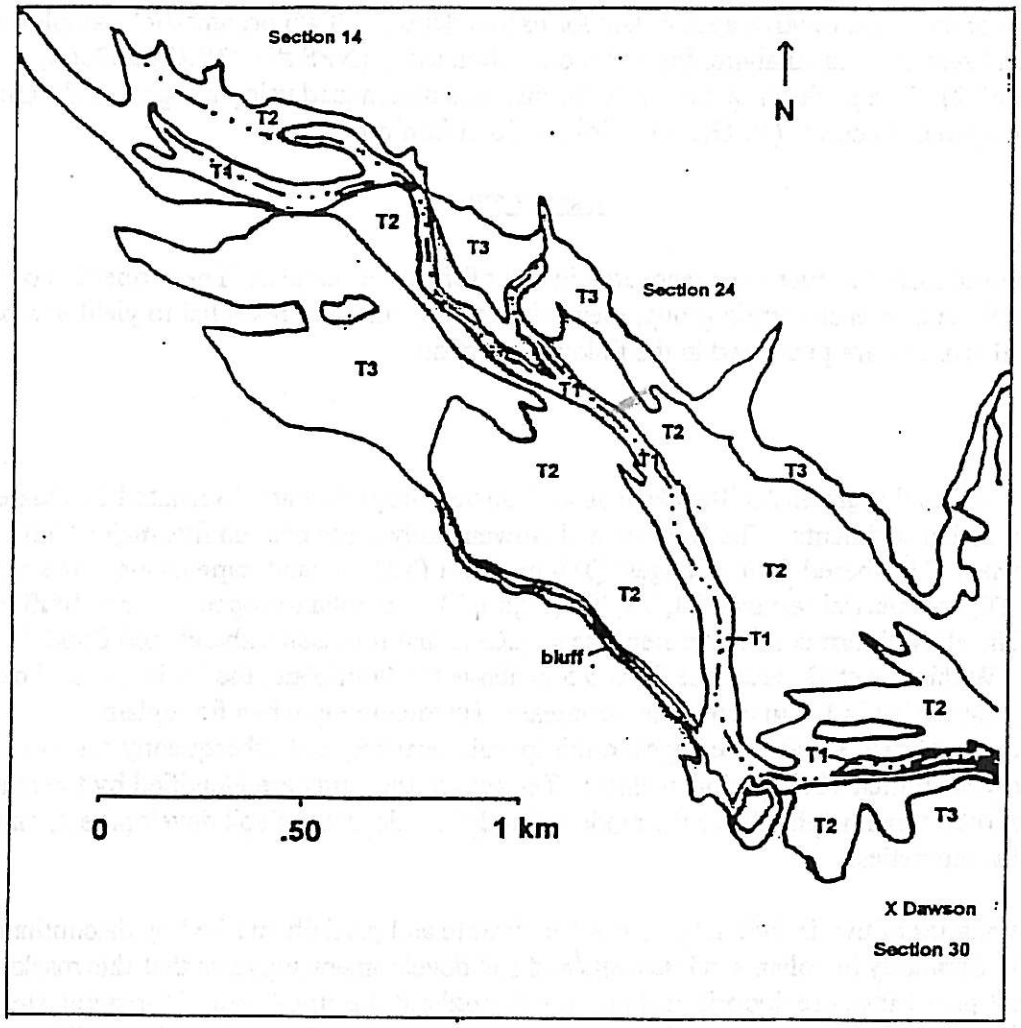

Figure 3. Geomorphic map of landforms.

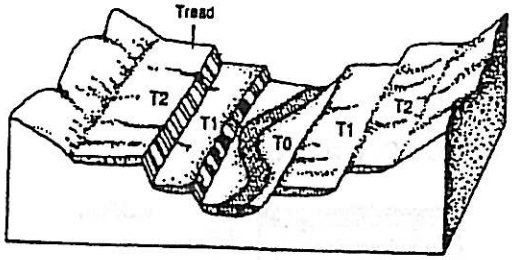

Figure 4. Diagram showing alluvial terrace sequence. After Waters (1992).

Floodplain (T0). Floodplain alluvium consists of very coarse to coarse-grained, poorly-sorted, and bedded alluvial sands (Figure 5; Appendix A). The surface soil exhibits A/C horizons (Figure 2; Appendix A, Core 26). Such weak soil development implies the alluvium is very young. We suggest the floodplain sediments are too young to yield *in situ*, cultural materials related to the 1864 massacre.

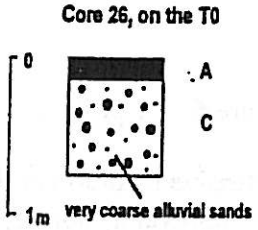

Figure 5. T0 profile.

T1 Terrace. The T1 alluvium is composed of coarse to very coarse-grained, poorly-sorted, bedded alluvial sand mantled by a thin (10 cm), discontinuous, eolian sand sheet (Figure 6; Appendix A). The T1 soils in the eolian sands are slightly more developed or stronger than the T0 soils (e.g., A/Bw horizons; Appendix A, Cores 2, 3). The alluvium also contains buried paleosols with horizons that are more complex (i.e., Abt; Figure 6). The presence of these buried paleosols indicates multiple periods of aggradation and landscape stability are preserved in the T1 stratigraphic sequence. Based on its geomorphic position, strength of the modern soil, and the presence of buried paleosols, the T1 terrace is considered older than the floodplain alluvium.

Therefore, its potential to of yield *in situ* 1864 period artifacts is higher than the T0.

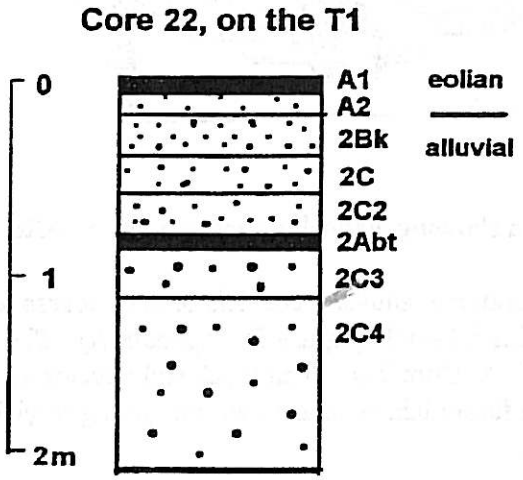

Figure 6. T1 profile.

T2 Terrace. The T2 is the most extensive landform in the Dawson Locality #1. It consists of very coarse to coarse-grained, poorly to moderately-sorted, sandy alluvium that is capped by up to 80 cm of medium to coarse, well-sorted, eolian sands (Figure 7; Appendix A). The modern soil in the eolian sand exhibits A/Bw/C horizons. At least three buried paleosols were observed within the alluvial sands. The buried paleosols in the alluvium exhibit Abk and Abtk horizons (Figure 7). The strength and complexity of paleosols suggests relatively longer periods of landscape stability. In turn, this strength also suggests that the complex T2 paleosols predate the 1864 massacre (see Karlstrom 1988). The presence of a structural Bw soil horizon at 19 cm in the T2 eolian sediments is important (Appendix A; Core 7). It implies that historic human or geologic disturbance has not occurred. This lack of disturbance also suggests that, if present, cultural material in and below the Bw horizon is *in situ*. The fact that eolian sediments are conducive to the preservation of *in situ* cultural materials and that they might be the right age, suggests that the T2 eolian sands are a good place to find evidence of the Sand Creek Massacre. The few 1864-period artifacts recovered by NPS during the 1997 archaeological survey were recovered in the upper 10-20 cm of eolian sands in this area (Douglas Scott, personal communication, December 1998).

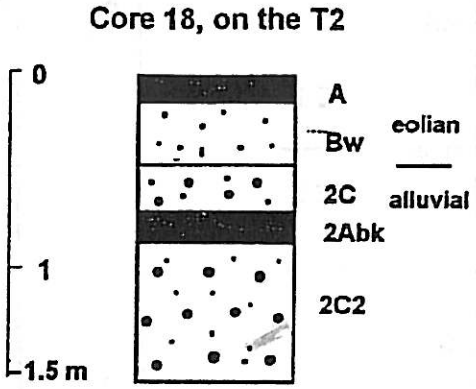

Figure 7. T2 profile.

T3 Terrace. Two eolian units with a total depth of > 528 cm were identified on what appears to be alluvial terrace T3 (EI and E II; Figure 8, Appendix A). Core 1 revealed two, medium-grained, well-sorted, sandy eolian deposits separated by a buried paleosol. Core sampling did not intercept the T3 alluvium, indicating that, at Dawson Locality #1, the T3 tread is deeply buried. The modern soil in the upper eolian unit (E II) exhibits an AC horizon (Figure 8; Appendix A). A buried and stripped paleosol with a cambic horizon (i.e., Bwb) defines the upper boundary of the lower eolian unit (E I). This Bwb horizon exhibits weak, fine, granular structure similar to the structural soil horizon noted in the T2 eolian sediments. As previously mentioned, the preservation potential for *in situ* cultural materials in eolian deposits is high. Thus, based on weak modern soil development, E II on the T3 may the potential to yield Sand Creek Massacre materials.

Eolian-Capped Bluff. Core 20 was in a bluff-top that is approximately 6.10 m above Big Sandy Creek (Figures 3 and 9). Core 20 revealed two well-sorted, medium-grained, eolian sand deposits. A weak modern soil A horizon is present in upper eolian unit suggesting it is a relatively young deposit (about 100 years; after Karlstrom 1988). A buried calcareous paleosol (Abk) in the lower eolian unit was noted at a depth of 77 cm below the surface (Figure 9; Appendix A). The presence of a calcareous paleosol implies that the basal eolian unit is too old to yield Sand Creek Massacre age materials (after Karlstrom 1988). Based on the relative age of the modern

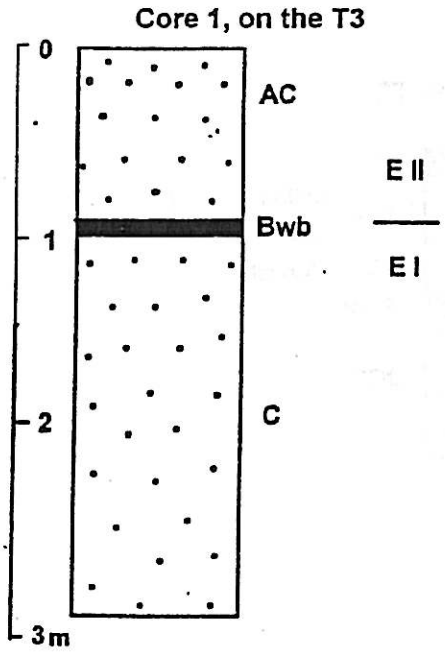

Figure 8. T3 profile.

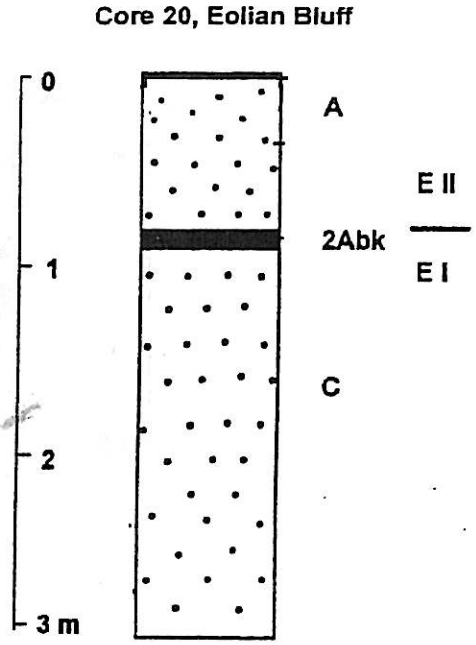

Figure 9. Eolian-capped bedrock bluff profile.

soil, it is possible that eolian unit E II has the potential to yield 1864-period artifacts.

14C at Dawson #1 and #2. In April 1999, LaRamie Soils Service drilled three cores at the Dawson Locality #1 to collect soil humate samples for radiocarbon dating. All cores were located on the T2 alluvial terrace. Radiocarbon #1 did not yield a buried paleosol acceptable for radiocarbon assay. Radiocarbon #2 revealed an organic paleosol developed in alluvial sands (2Abtk; Appendix A). Radiocarbon #3 contained an Abk horizon in eolian sands between 36-47 cm below the surface. Two bulk soil samples (RC#2, RC#3) were sent to Beta Analytic, Inc. for a mean residency date. Unfortunately, United Parcel Service lost the samples. Radiocarbon samples were subsequently collected from the T1 and T2 paleosols at Dawson Locality #3, thus minimizing the loss of the original samples.

Dawson Locality #2

The Dawson Locality #2 is upstream from Dawson Locality #1 at the North Dawson Bend (Figure 1; northwest corner of Section 24, T17S R46W). National Park Service historian Jerome Green identified this area as having potential to be part of the massacre site (personal

communication, 1999). Dawson Locality #2 terrains include alluvial terraces T2 and T3 of Big Sandy Creek.

T2 Terrace. The T2 stratigraphic sequence consists of coarse to very coarse-grained, moderate to poorly-sorted, bedded alluvial sands and gravels capped by coarse-grained, well-sorted, discontinuous, eolian sands (Appendix A; D2#3A). The T2 terrace sediments are at least three meters deep in this area and are capped by a 5-71 cm-thick eolian sand deposit. Modern soil development on the T2 terrace is weak. A/C and A/Bw/C horizon sequences were observed in both the eolian and alluvial sediments (Appendix A). Three paleosols with Ab and Abk horizons were present within the T2 alluvial sediments. Based on soil relative age-dating, the probability of recovering *in situ* 1864-period artifacts within the eolian sand and in the alluvium above the youngest buried paleosol is high. The presence of the carbonate-enriched and structural horizon paleosols (e.g., Abk) in the alluvium suggests that they and their host sediments are too old to yield Sand Creek Massacre materials.

T3 Terrace. The T3 alluvial sequence consists of coarse to very coarse-grained, moderately to poorly-sorted, bedded alluvial sands and gravels capped by coarse-grained, well-sorted, eolian sands. Here, the tread of the T3 is approximately 50 cm higher than the T2 tread. Modern T3 soils are weak and exhibit A/Bw horizons. Several paleosols with an Bkb and Abk horizons occur in the eolian sediments (Appendix A, Core D2#12), and no paleosols were noted within the T3 alluvium. Based on its geomorphic position, it is unlikely that the T3 alluvium contains *in situ* 1864-period artifacts. However, they may form a palimpsest on the T3 surface and could be present in weak soil horizons within the eolian sand cap.

Dawson Locality #3

The Dawson Locality #3, like the Dawson Locality #2, is near the Dawson North Bend (Figure 1). Landforms in this area include the Big Sandy Creek floodplain, and the T1, T2, and T3 alluvial terraces. LaRamie Soils Service cored seven localities on the three alluvial terraces and the probable site area (see Scott 1999). Since the National Park Service located the site in this area, and we replaced the lost the original ^{14}C samples., we collected organic-rich sediments for radiocarbon assay.

T1 Terrace. The T1 is composed of coarse to very coarse-grained, poorly-sorted, sand overlain by fine sandy and silty clay loams. The modern soil on the T1 terrace includes A/C and A/Bw/C horizons. Core D3#5 revealed a buried organic paleosol (i.e., Ab horizon) 23 cm below surface (Figure 10; D3#5). Soil humates from this paleosol returned a radiocarbon age of 1030±70 yr. BP (Beta 133618; Appendix B). The position of the dated paleosol indicates that *in situ* Sand Creek Massacre cultural materials are limited to the alluvium between the surface and the buried Ab horizon (i.e., upper 23 cm). Further, because fine-textured alluvium represents a lower-energy depositional environment, the potential for artifact integrity is high within the upper 23 cm.

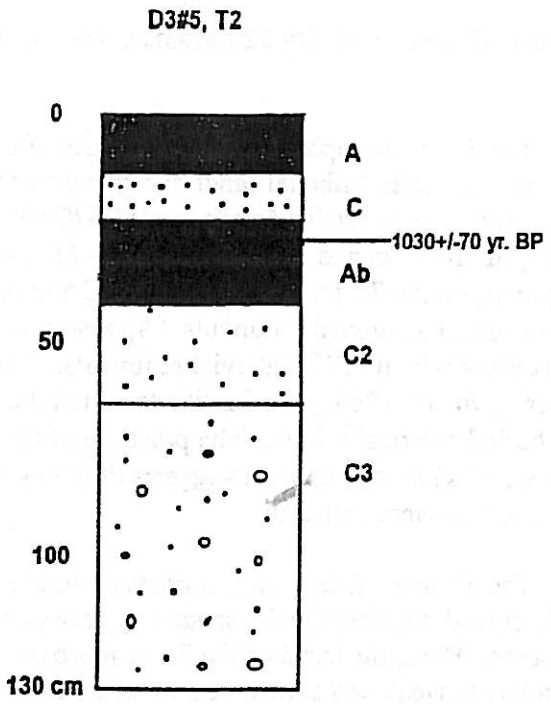

Figure 10. Profile of D3#5.

An intact, buried cache feature of .58-caliber bullets (FS# 1106) was encountered at 23 cm below the surface during a NPS metal detector survey of the T1 (see Scott 1999:18). An uncontrolled excavation was carried out, and LaRamie Soils Service examined the feature's geological context. This feature was encased in a medium-grained, well-sorted, sand overlain by a fine-grained overbank deposit (Figure 11). Evidence of historic geologic or agricultural disturbance was not noted. This overbank deposit was not observed in a core sample taken approximately 50 cm from the feature (Core D3#1; Appendix A). Due to the absence of a plow zone, poorly-sorted flood deposits, and the presence of an undisturbed modern soil, we feel the T1 alluvium overlying the feature was undisturbed. High velocity creek flooding would have scattered the .58 caliber bullets across the floodplain.

T2 Terrace. The T2 alluvium at Dawson Locality #3 consists of coarse to very coarse-grained, poorly sorted, bedded sands overlain by fine-grained, silty and sandy clay loam-textured sediments (D3#2, Appendix A). Modern soil development on the T2 terrace included A/C and A/Bw/C horizons. We observed a possible disturbance zone in the upper 10 cm of the T2 terrace. Two buried paleosols with Abk horizons were also noted. Core D3#6 revealed the first of these buried organic paleosols (i.e., Abk horizon) below a Bk horizon at 97 cm below surface (Figure 12; D3#6). Soil humates from the Abk horizon returned a radiocarbon age of 2390±110 yr. BP (Beta 133619; Appendix B). The position of the dated paleosol indicates that *in situ* Sand Creek Massacre cultural materials are limited to the upper 97 cm of T2 alluvium.

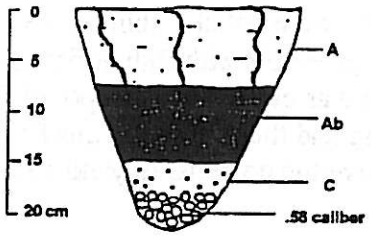

Figure 11. Profile of FS#1106.

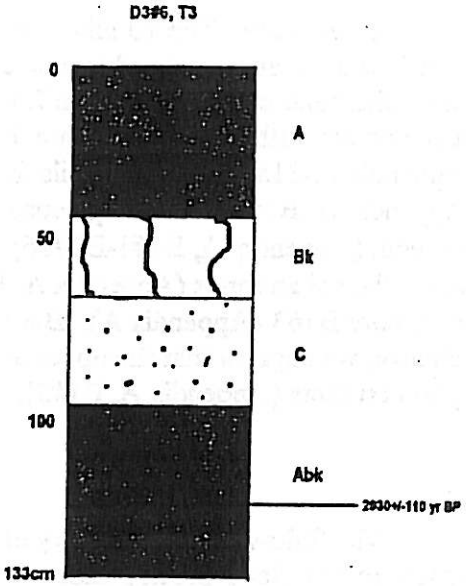

Figure 12. Profile of D3#6.

Bowen Locality #1

Bowen Locality #1 is at Bowens' South Bend of Big Sandy Creek (Figure 1; middle of section 14, T17S R46W). Charles and Sheri Bowen believe that this was the site of Black Kettle's village. Dominant landforms at Bowen Locality #1 are alluvial terraces T1, T2 and T3.

T1 Terrace. The T1 alluvium is composed of coarse-grained, moderately to poorly-sorted, sand interbedded with finer-textured sediments. Modern T1 soils consist of A/Bw/Btss/BC/C horizons (Appendix A, Core B1#16). Paleosols were not observed within the T1 alluvium. Although the presence of a Bt horizon suggests the modern soil is old (see McFadden 1982, Birkeland 1984), its development is considered to be the result of shrink-swell processes on fine-grained parent material. Based on the position of dated paleosol (i.e., 23 cm below the surface) at Dawson Locality #3, the potential of the T1 here is limited to the upper alluvium.

T2 Terrace. The T2 alluvium is composed of coarse-grained, moderately to poorly-sorted, sand and sandy clay loam. The discontinuous eolian sands were not encountered at this locality. Modern soils within the T2 alluvium are weak (e.g., A/Bw horizons) and buried paleosols are present in the alluvium (e.g., Bkb, Abk horizons). As mentioned previously, the Dawson Locality #3 has a dated, buried paleosol (i.e., Abk horizon) within the T2 alluvium at 97 cm below the surface (Appendix A, D3#6). The position of the dated paleosol suggests the upper 97 cm of T2 alluvium at Bowen Locality #1 is capable of yielding *in situ* 1864-period artifacts.

T3 Terrace. The T3 alluvium consists of coarse to very coarse-grained, moderately sorted, sands that are capped by coarse-grained, well-sorted, and discontinuous, eolian sands. The eolian sand cap at the Bowen Locality #1 is thick (151 cm; Appendix A, B1#3). Modern soil development within the T3 alluvium is relatively strong, exhibiting A/Bw/Bk/Bk2/C/C2 horizons (Appendix A B1#4). Modern soils formed within the eolian sands have A/Bw horizons (Appendix A, B1#3).. Buried paleosols with Ab and Bkb horizons were noted within the T3 alluvium (Appendix A, B1#1-B1#16). We also observed buried paleosols with Bkb horizons within the eolian sands (Appendix A, B1#3). This Bkb paleosol was observed at a depth of 50 cm in core B1#3 (Appendix A). Based on soil relative-age dating and the position of this Bkb paleosol, we suggest that the upper 50 cm of eolian sediments have the potential to yield 1864-period artifacts (Appendix A, B1#3).

DISCUSSION

The following is a summary of terrain characteristics and their respective potential to yield buried, *in situ*, Sand Creek Massacre cultural materials. Figure 13 is a generalized cross-section of the five terrain types encountered in the study area.

The Big Sandy Creek floodplain, or T0 landform, spans an approximately 20-100 m wide area adjacent to the intermittent creek channel (Figure 13). Floodplain sediments consist of coarse to very coarse-grained, poorly-sorted, alluvial sands. Modern floodplain soils are weak and exhibit A/C soil horizons (Appendix A, Core 26). These are very recent deposits, and Sand Creek Massacre-period artifacts within these flood plain sediments are probably redeposited.

The tread or surface of alluvial terrace T1 is approximately half of a meter above the modern floodplain. The T1 sediments consist of coarse-grained, sandy alluvium mantled by as much as 10 cm of medium-grained, well-sorted, discontinuous, eolian sands (Appendix A). This discontinuous eolian cap is most prominent at Dawson Locality #1, and was not observed at Dawson #3 and Bowen #1 Localities. The modern soil within the T1 is weak to moderately developed in the eolian sands and the alluvium. Both exhibit A/C, A/Btss, and A/Bw/Bt/BC/C soil horizons. Two buried paleosols with Ab and Abt horizons were noted within the T1 alluvium at the Dawson #1 and #3 Localities (Appendix A, Cores 21,22, D3#5, D3#6). At Dawson Locality #3, a paleosol in T1 alluvium yielded a radiocarbon age of 1030±70 yr. BP (Beta 133618; Appendix B). The position of the dated paleosol suggests that *in situ* Sand Creek Massacre cultural materials are limited to the upper 22 cm of T1 alluvium (Appendix A, Core D3#5).

The elevation of the T2 tread is approximately one meter above the floodplain. The T2 alluvium consist of coarse to very coarse-grained, poorly-sorted, sands. At Dawson Localities #1, and #2, the alluvium is capped with approximately 50-60 cm of medium to coarse-grained, well-sorted, discontinuous, eolian sands. The eolian sands were encountered only once at Bowen Locality #1 (i.e., B1#3), and were not present Dawson Locality #3. The T2 alluvium commonly exhibits at least one buried paleosol with an Ab horizon (Appendix A, Cores 6-19, 24, and 25).

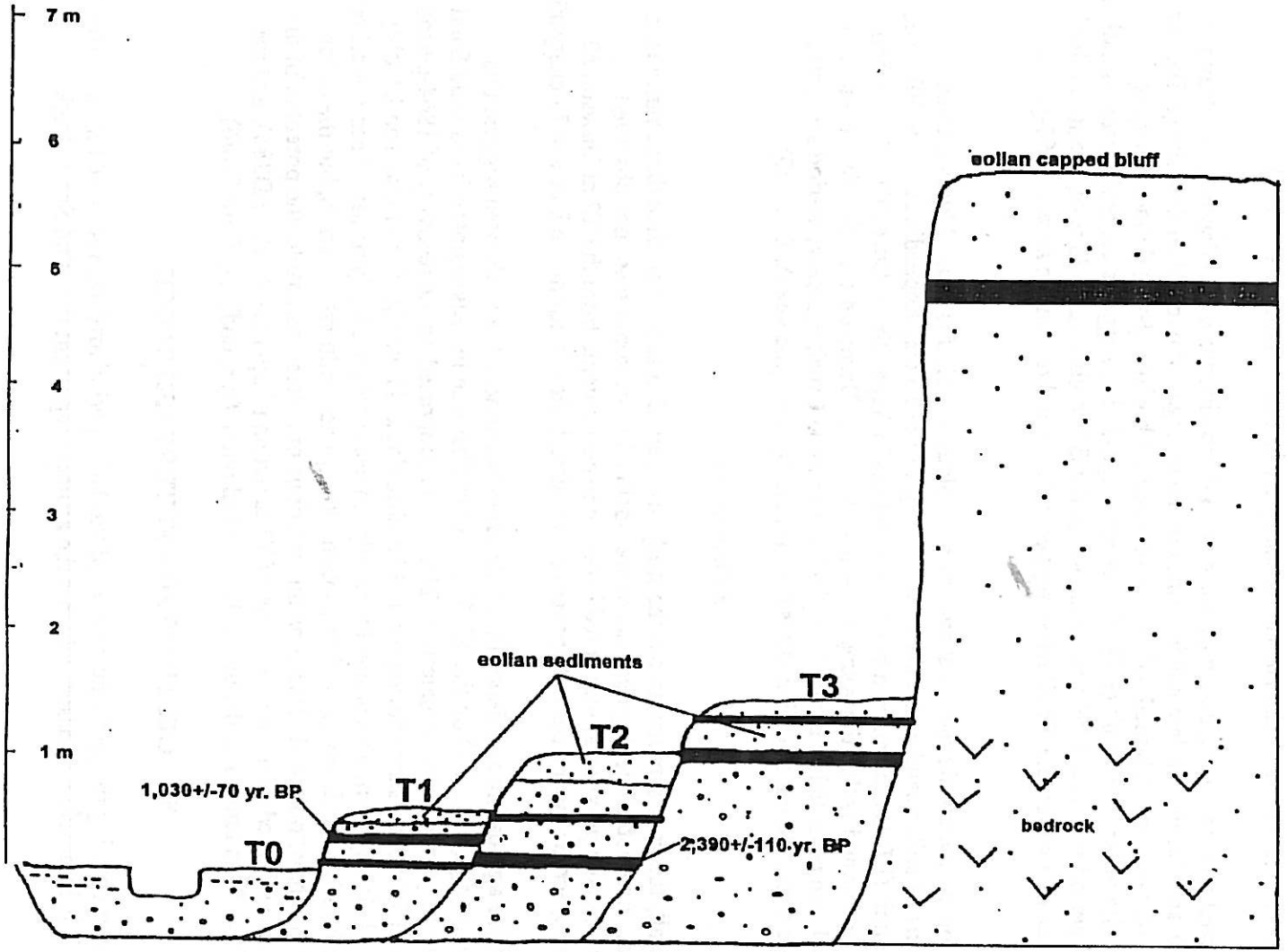

Figure 13. Schematic cross-section of alluvial terraces in the Big Sandy Creek drainage.

The modern soil in the eolian sands exhibits A/Bw/Bk/C horizons. Buried at 97 cm below the surface at Dawson Locality #3, organics from an Abk paleosol returned a radiocarbon age of 2390±110 yr. BP (Beta 133619, Appendix B; Appendix A, D3#6). Based on the position of the dated paleosol, the potential of the T2 is limited to the upper 97 cm of alluvium. The discontinuous eolian sediments that cap the T2 are young enough to contain 1864-period materials. This was proven at the Dawson Locality #1 in 1997 (Scott et al. 1998).

Alluvial terrace T3 is mantled by one or two discontinuous eolian deposits. At Dawson Localities #1 and #2, the modern soil is formed in the younger of two eolian deposits (E II), and exhibits an AC horizon. A buried paleosol with a cambic horizon (Bwb) defines the upper boundary of the older eolian unit (E I). Soil relative age-dating suggests cultural materials dating to the 1864 period will most likely be found within the E II eolian sand. In turn, the strength of soils and paleosols within the T3 alluvium suggest it is too old to contain *in situ* 1864-period artifacts.

At approximately six meters above the floodplain, the bluff is capped by two thick accumulations of eolian sand at the Dawson Locality #1 (≥916 cm; Appendix A, Core 20). The older eolian unit (EI) is defined by a buried Abk paleosol (Appendix A; Core 20). The modern soil A horizon formed within the younger eolian unit (E II). Based on the soil relative age of the Abk paleosol, the potential of the bluff to yield *in situ* Sand Creek Massacre-period artifacts is limited to the upper 76 cm of eolian sands (i.e., unit E II; see Appendix A, Core 20).

SUMMARY

Overall, the core samples across the study area revealed less subsurface disturbance than we expected. Artifact/gravel lag deposits or well-defined plow zones were not observed. However, a possible plow zone was noted in only one core sample from the T2 at Dawson #3 Creek flooding across the T1 did not appear to be a disturbance factor at the Dawson Locality #3.

Relative age-dating and depositional histories throughout the study area suggest that eolian deposits (e.g., Unit EII) on the T2, T3, and bluff have an increased potential to yield Sand Creek Massacre-period cultural materials. This is also supported by the recovery of 1864-period artifacts in the T2 eolian sands during the 1997 archaeological investigation of Dawson Locality #1 (Scott et al. 1998). Artifacts within the floodplain sediments are likely to have been reworked. The T3 alluvium is considered too old to contain 1864-period cultural materials, but the eolian sands that cap it have potential. Based on the positions of a dated paleosols, the potential of the T1 appears to be limited to the upper 23 cm of T1 alluvium (Appendix A, Core D3#5), and the potential of the T2 is limited to the upper 97 cm of alluvium (Appendix A, Core D3#6).

SUGGESTIONS FOR FUTURE RESEARCH

Without defining the geologic context of the 1864-period artifacts recovered at Dawson Locality #3, it is impossible to assess whether the artifacts represent the 1864 Sand Creek

Massacre site or a historic artifact palimpsest. We recommend the depths of each artifact and their geological context be recorded in order to address this question. The stratigraphic position, or vertical distribution, of recovered artifacts can be tied into our dated geomorphic model of the site area. In turn, this would, give absolute age control to the artifacts recovered in Dawson Locality #3. We support Scott (1999:35) who states:

> "The primary research question to be answered with the archaeological data is whether the artifacts recovered are the remains of Black Kettle's village that was attacked by the Colorado Volunteer Calvary on November 29, 1864. The artifacts, their distribution on the landscape, and ***the context in which they were recovered*** provide the answer" (emphasis ours).

Finally, understanding the geologic context of these 1864-period artifacts is crucial to accurately assessing whether or not the massacre site has been located.

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APPENDIX A

CORE DESCRIPTIONS

Dawson #1 Area, December 1998
CORE 1
Total Depth: 528 cm
Landform: T3

Soil Horizon	Stratum	Depth (cm)	Description
AC	eolian E II	0-76	Yellowish brown (10YR 5/4 d) well-sorted medium sand; weak medium subangular blocky; loose, nonsticky, nonplastic; common fine, slightly effervescent; clear smooth boundary.
Bwb	eolian E I	76-82	Very pale brown (10YR 8/2 d) well-sorted medium sand; strongly effervescent; abrupt smooth boundary.
C	eolian E I	82-280	Yellowish brown (10YR 5/4 d) well-sorted medium sand; weak medium subangular blocky structure; loose, nonsticky, nonplastic; common fine; slightly effervescent; clear smooth boundary.

CORE 2
Total Depth: 272 cm
Landform: T1

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-10	Dark greyish brown (10YR 4/2 d) sandy loam; weak fine subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine; slightly effervescent; clear smooth boundary.
C	alluvial	10-33	Pale brown (10YR 6/3 d) well-sorted coarse sand; slightly effervescent; clear smooth boundary.
C2	alluvial	33-53	Pale brown (10YR 6/3 d) poorly-sorted very coarse; slightly effervescent; clear smooth boundary.
C3	alluvial	53-137	Very pale brown (10YR 7/3 d) well sorted coarse sand; slightly effervescent; clear smooth boundary.
C4	alluvial	137-212	Very pale brown (10YR 7/3 d) poorly-sorted very coarse sand; slightly effervescent.

CORE 3
Total Depth: 299 cm
Landform: T1

Soil Horizon	Stratum	Depth (cm)	Description

A	alluvial	0-15	Very dark greyish brown (10YR 3/2 d) clay loam; strong medium angular blocky structure; very hard, firm, sticky, plastic; few distinct cutans on ped faces; common very fine roots; very slightly effervescent; clear smooth boundary.
Bw	alluvial	15-28	Light yellowish brown (10YR 6/4 d) sandy clay loam; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine roots; very slightly effervescent; clear smooth.
C	alluvial	28-42	Very pale brown (10YR 7/4 d) well-sorted coarse sand; weak fine subangular blocky structure; soft, very friable, nonsticky, nonplastic; few very fine roots; no reaction; abrupt smooth boundary.
2Abtk	alluvial	42-54	Very dark greyish brown (10YR 3/2 d) silty clay; strong coarse subangular blocky; very hard, very firm, sticky, plastic; common distinct cutans on ped faces; common distinct sand coats on ped faces; common prominent $CaCO_3$ filaments and very strongly effervescent; common very fine roots; abrupt smooth boundary.
2C	alluvial	54-68	Light yellowish brown (10YR 6/4 d) well sorted coarse sand; few very fine roots; strongly effervescent; clear smooth boundary.
2C2	alluvial	68-90	Light reddish brown (2.5YR 6/4 d) moderately sorted coarse sand; very slight reaction; clear smooth boundary.
2C3	alluvial	90-128	Light yellowish brown (10YR 6/4 d) moderately sorted coarse sand; strongly effervescent; clear smooth boundary.
2C4	alluvial	128-180	Light yellowish brown (10YR 6/4 d) poorly sorted very coarse sand; strongly effervescent; clear smooth boundary.
2C5	alluvial	180-210	Yellowish brown (10YR 5/6 d) laminated clay; common distinct mottles, reddish brown (2.5YR 5/3 d and m); many distinct cutans on ped faces; many very fine roots; noneffervescent; abrupt smooth boundary.
2C6	alluvial	210-290	Light yellowish brown (10YR 6/4 d) poorly sorted coarse sand; strongly effervescent.

CORE 4
Total Depth: 311 cm
Landform: T1

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-22	Very dark greyish brown (10YR 3/2 d) clay; moderate coarse subangular blocky structure; slightly hard, firm, sticky, plastic; common cutans on ped faces; common fine roots; very slightly effervescent; clear smooth.
2C	alluvial	22-33	Light gray (10YR 7/2 d) poorly sorted very coarse and coarse sand; weak fine granular structure; noneffervescent; abrupt smooth boundary.

2Abt	alluvial	33-44	Very dark greyish brown (10YR 3/2 d) clay loam; moderate medium subangular blocky structure; hard, firm, sticky, plastic; common distinct cutans on ped faces; few very fine roots; very slightly effervescent; abrupt smooth boundary.
2C	alluvial	44-87	Dark yellowish brown (10YR 4/6 d) moderately sorted very coarse mottled sand; mottles: yellowish red (5YR 5/8 m); few fine to medium rounded iron concretions; noneffervescent; clear smooth boundary.
2C2	alluvial	87-227	Dark yellowish brown (10YR 4/6 d) moderately sorted very coarse sand; noneffervescent.

CORE 6
Total Depth: 280 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian E II	0-23	Dark yellowish brown (10YR 4/4 d) sandy clay loam; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, nonplastic; many fine to coarse; slightly effervescent; clear smooth boundary.
C	eolian E II	23-80	Very pale brown (10YR 8/3 d) well sorted medium sand; slightly effervescent; abrupt smooth boundary.
Abk	eolian E I	80-88	Brown (10YR 5/3 d) sandy clay loam; weak fine subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; few irregular segregated calcium carbonate filaments, strongly effervescent; abrupt smooth boundary.
C2	eolian E I	88-140	Very pale brown (10YR 8/3 d) well sorted medium sand; slightly effervescent; clear smooth boundary.
2Ab	alluvial	140-150	Yellowish brown (10YR 5/6 d) sandy loam; weak fine subangular blocky structure; slightly hard, very friable, nonsticky, nonplastic; slightly effervescent; clear smooth.
2C	alluvial	150-172	Light yellowish brown (10YR 6/4 d) poorly sorted coarse sand; noneffervescent.

CORE 7
Total Depth: 710 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-19	Brown (10YR 4/3 d) sandy loam; weak medium subangular blocky structure; slightly hard, very friable, slightly plastic; common fine; strongly effervescent; clear smooth boundary.

Bw	eolian	19-51	Yellowish brown (10YR 5/4 d) loamy sand; weak medium subangular blocky structure; slightly hard, very friable, nonplastic; few fine; strongly effervescent; clear gradual boundary.
C	eolian	51-78	Yellowish brown (10YR 5/4 d) well-sorted coarse sand; slightly effervescent; clear smooth boundary.
2Abk	alluvial	78-81	Brown (10YR 4/3 d) sandy clay loam; weak fine subangular blocky structure; hard, friable, slightly sticky, slightly plastic; strongly effervescent, common (7%) fine segregated calcium carbonate filaments; abrupt smooth boundary.
2C	alluvial	81-255	Yellowish brown (10YR 5/4 d) well-sorted coarse alluvial sands; noneffervescent.

CORE 8
Total Depth: 834 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-19	Brown (10YR 4/3 d) sandy clay loam; weak fine to medium subangular blocky structure; slightly hard, very friable, slightly sticky, nonplastic; many fine roots; slightly effervescent; clear smooth boundary.
Bw	eolian	19-57	Pale brown (10YR 6/3 d) sandy loam; moderate medium subangular blocky structure; slightly hard, very friable, nonsticky, nonplastic; few fine; abrupt smooth boundary.
2C	alluvial	57-160	Very pale brown (10YR 7/3 d) poorly sorted sand and granules; noneffervescent; abrupt smooth boundary.
Ab	alluvial	160-169	Brown (10YR 5/3 d) sandy loam, dark brown (10YR 4/4 m); weak fine subangular blocky; soft, very friable, nonsticky, nonplastic; few distinct mottles, yellowish brown (10YR 5/6 m); abrupt smooth boundary.
2C2	alluvial	169-280	Pale brown (10YR 6/3 d) well sorted very coarse sand; noneffervescent.

CORE 9
Total Depth: 204 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-18	Yellowish brown (10YR 5/4 d) sandy loam; weak medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; few fine, slightly effervescent; clear smooth boundary.
Bw	eolian	18-40	Reddish brown (2.5YR 5/4 d) sandy loam; weak medium subangular blocky structure; slightly hard, very friable, nonsticky, nonplastic; few fine; slightly effervescent; clear smooth boundary.

2Abtk	alluvial	40-50	Light yellowish brown (10YR 6/4 d) sandy clay, 5% gravel; strong medium angular blocky structure; very hard, very firm, sticky, slightly plastic; few faint cutans on ped faces; few fine irregular soft carbonate masses; violently effervescent; abrupt smooth boundary.
2C	alluvial	50-104	Yellowish brown (10YR 5/4 d) moderately sorted coarse; very slightly effervescent; clear smooth boundary.
2Abk	alluvial	104-113	Dark gray (10YR 4/1 d) sandy clay loam, 10% gravel; strong medium subangular blocky structure; very hard, very firm, sticky, slightly plastic; common mottles, strong brown (7.5 YR 5/6 m); common fine irregular soft carbonate masses, violently effervescent; clear smooth boundary.
2C2	alluvial	113-159	Yellowish brown (10YR 5/4 d) moderately sorted very coarse sand; very slightly effervescent; clear smooth boundary.
2C3	alluvial	159-169	Strong brown (7.5YR 5/6 d) moderately sorted very coarse sand; noneffervescent.

CORE 10
Total Depth: 196 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-17	Brown (10YR 5/3 d) sandy clay loam; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, nonplastic; common fine roots; slightly effervescent; clear smooth boundary.
Bw	eolian	17-42	Light reddish brown (2.5YR 6/4 d) sandy loam; moderate fine subangular blocky structure; slightly hard, very friable, no sticky, nonplastic; common fine roots; slightly effervescent, clear smooth boundary.
2Abk	alluvial	42-50	Dark yellowish brown (10YR 4/4 d) sandy clay loam; strong coarse angular blocky structure; hard, firm, sticky, plastic; 5% gravel; common fine irregular soft carbonate masses, violently effervescent.
2C	alluvial	50-190	Very pale brown (10YR 7/4 d) moderately sorted very coarse sand; noneffervescent.

CORE 11
Total Depth: 248 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian E II	0-18	Brown (10YR 5/3 d) sandy clay loam; moderate medium subangular blocky structure; slightly hard, firm, slightly sticky, nonplastic; common fine; slightly effervescent; clear smooth boundary.

Bw	eolian E II	18-36	Yellowish brown (10YR 5/4 d) sandy loam; weak medium subangular blocky structure; soft, friable, nonsticky, nonplastic; common fine; slightly effervescent; abrupt smooth boundary.
Abk	eolian E I	36-40	Yellowish brown (10YR 5/4 d) sandy clay; moderate medium angular blocky structure; hard, firm, sticky, plastic; many coarse rounded calcium carbonate nodules; clear smooth boundary.
Bw2	eolian E I	40-49	Yellowish brown (10YR 5/4 d) sandy loam; weak medium subangular blocky structure; soft, friable, nonsticky, nonplastic; common fine; slightly effervescent; abrupt smooth boundary.
2C	alluvial	49-192	Yellowish brown (10YR 5/4 d) moderately sorted, very coarse sand; very slightly effervescent.

CORE 12
Total Depth: 317
Landform: T2

Soil · Horizon	Stratum	Depth (cm)	Description
A	eolian	0-22	Brown (10YR 5/3 d) sandy clay loam, brown (10YR 4/3 m); moderate medium subangular blocky; slightly hard, friable, slightly sticky, nonplastic; many fine; slightly effervescent; abrupt smooth.
Bw	eolian	22-45	Yellowish brown (10YR 5/4 d) sandy loam, dark yellowish brown (10YR 4/4 m); weak fine subangular blocky; slightly hard, very friable, nonsticky, nonplastic; many fine to coarse; slightly effervescent; clear smooth.
2C	alluvial	45-64	Yellowish brown (10YR 5/4 d) poorly sorted coarse and very coarse alluvial sand, dark yellowish brown (10YR 4/4 m); no reaction; abrupt boundary.
2Abk	alluvial	64-69	Yellowish brown (10YR 5/4 d) sandy clay loam, yellowish brown (10YR 4/4 m); mottles, strong brown (7.5YR 5/6 m); very abundant rounded calcium carbonate concretions and violent effervescence; clear boundary.
2C2	alluvial	69-251	Yellowish brown (10YR 5/4 d) poorly sorted coarse and very coarse alluvial sand, dark yellowish brown (10YR 4/4 m); no reaction.

CORE 13
Total Depth: 202cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-19	Dark yellowish brown (10YR 4/4 d) sandy clay loam; moderate coarse subangular blocky structure; hard, firm, slightly sticky, slightly plastic; common fine, slightly effervescent; clear smooth boundary..
Bw	eolian	19-34	Yellowish brown (10YR 5/4 d) sandy loam; weak medium subangular blocky; slightly hard, friable, nonsticky, nonplastic; few fine roots; abrupt smooth boundary.
C	eolian	34-54	Light yellowish brown (10YR 6/4 d) well sorted coarse sand; slightly effervescent; clear smooth boundary.
2C	alluvial	54-106	Light yellowish brown (10YR 6/4 d) poorly sorted coarse sand; noneffervescent; clear smooth boundary.
2Abtg	alluvial	106-142	Dark yellowish brown (10YR 4/4 d) sandy clay, 10% gravel; mottles: yellowish red (5YR 5/8 m); common cutans on ped faces; noneffervescent; clear smooth boundary.
2C2	alluvial	142-183	Yellowish brown (10YR 5/4 d) well sorted coarse sand; noneffervescent.

CORE 14
Total Depth: 93 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-17	Dark yellowish brown (10YR 4/4 d) sandy loam; moderate medium subangular blocky structure; soft, friable, nonsticky, nonplastic; common fine; very slightly effervescent; clear smooth boundary.
Bw	eolian	17-38	Yellowish brown (10YR 5/4 d) sandy loam; weak fine subangular blocky; soft, very friable, nonsticky, nonplastic; slightly effervescent; clear smooth boundary.
C	eolian	38-45	Light yellowish brown (10YR 6/4 d) moderately sorted coarse sand; very slightly effervescent; abrupt smooth boundary.
2Abtk	alluvial	45-51	Brown (10YR 5/4 d) sandy clay, 5% gravel; strong coarse angular blocky structure; very hard, very firm, sticky, plastic; common distinct cutans on ped faces; few fine irregular soft carbonate masses, very strong effervescence; clear smooth boundary.
2C	alluvial	51-65	Light yellowish brown (10YR 6/4 d) moderately sorted, coarse alluvial sand; slightly effervescent.

CORE 15
Total Depth: 127 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-20	Dark yellowish brown (10YR 4/4 d) sandy clay loam, dark yellowish brown, (10YR 3/4 m); moderate medium subangular blocky; slightly hard, friable, slightly sticky, nonplastic; common fine; slightly effervescent; clear smooth.
Bw	eolian	20-49	Grayish brown (10YR 5/2 d) sandy loam, dark grayish brown (10YR 5/1 m); weak medium subangular blocky; soft, very friable, nonsticky, nonplastic; common fine; slightly effervescent; abrupt smooth.
2C	alluvial	49-76	yellowish brown (10YR 5/4 d) moderately sorted very coarse sand, dark yellowish brown (10YR 4/4 m); no reaction.

CORE 16
Total Depth: 200 cm
Landform: T2

Stratum	Stratum	Depth (cm)	Description
A	eolian	0-17	Yellowish brown (10YR 5/4 d) sandy clay loam; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, nonplastic; common fine; slightly effervescent; clear smooth boundary.
Bw	eolian	17-39	Yellowish brown (10YR 5/6 d) sandy loam; weak medium subangular blocky structure; slightly hard, slightly friable, nonsticky, nonplastic; slightly effervescent; clear smooth boundary.
2C	alluvial	39-67	Light yellowish brown (10YR 6/4) moderately sorted coarse sand; noneffervescent; abrupt smooth boundary.
2Abk	alluvial	67-74	Dark yellowish brown (10YR 4/4 d) sandy clay loam; strong medium subangular blocky; hard, firm, sticky, slightly plastic; very strongly effervescent; abrupt smooth boundary.
2C2	alluvial	74-185	Light yellowish brown (10YR 6/4) moderately sorted coarse sand; noneffervescent.

CORE 17
Total Depth: 345 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-9	Brown (10YR 5/3 d) sandy loam; weak fine to medium subangular blocky structure; soft, friable, nonsticky, nonplastic; few fine; very slightly effervescent; clear smooth boundary.
2C	alluvial	9-56	Very pale brown (10R 7/3 d) moderately sorted very coarse sand; slightly effervescent.

CORE 18
Total Depth: 239 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-19	Dark yellowish brown (10YR 4/4 d) sandy loam; weak medium subangular blocky structure; slightly hard, friable, nonsticky nonplastic; many fine to coarse roots; slightly effervescent; clear smooth boundary.
Bw	eolian	19-47	Yellowish brown (10YR 5/4 d) loamy sand; weak medium granular; soft, very friable; nonsticky, nonplastic; few fine; slightly effervescent; abrupt smooth boundary.
2C	alluvial	47-77	Yellowish brown (10YR 5/4 d) moderately sorted coarse sand; slightly effervescent; abrupt smooth boundary.
2Abk	alluvial	77-85	Yellowish brown (10YR 5/4 d) sandy loam; weak medium subangular blocky structure; slightly hard, very friable, nonsticky, nonplastic; strongly effervescent; clear smooth boundary.
2C2	alluvial	85-151	Yellowish brown (10YR 5/4 d) well sorted; slightly effervescent.

CORE 19
Total Depth: 89 cm
Landform: T2

Stratum	Stratum	Depth (cm)	Description
A	eolian	0-19	Dark yellowish brown (10YR 4/4 d) sandy loam; weak moderate subangular blocky structure; slightly hard, very friable, nonsticky, nonplastic; few fine; slightly effervescent; clear smooth boundary.
Bw	eolian	19-31	Yellowish brown (10YR 5/4 d) sandy loam; weak coarse granular; soft, very friable, nonsticky, nonplastic; slightly effervescent; clear smooth boundary.

2C	alluvial	31-64	Yellowish brown (10YR 5/4 d) poorly sorted, coarse and very coarse sand; noneffervescent; abrupt smooth boundary.
2Abk	alluvial	64-78	Yellowish brown (10YR 5/4 d) sandy loam; moderate coarse subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; very strongly effervescent; few fine irregular soft carbonate masses.

CORE 20
Total Depth: 916 cm
Landform: bluff

Stratum	Stratum	Depth (cm)	Description
A	eolian E II	0-77	Dark yellowish brown (10YR 4/4 m) weak medium subangular blocky structure; soft, very friable, nonsticky, nonplastic; effervescent; gradual smooth boundary
2Abk	eolian E I	77-89	Yellowish brown (10YR 5/4 m) loamy sand; weak coarse granular structure; soft, very friable, nonsticky, nonplastic; strongly effervescent; few fine irregular carbonate filaments; clear smooth boundary.
C	eolian E I	89-303	Yellowish brown (10YR 5/4 m) loamy sand; few fine irregular carbonate filaments.

CORE 21
Total Depth: 395 cm
Landform: T1

Stratum	Stratum	Depth (cm)	Description
A	alluvial	0-18	Dark yellowish brown (10YR 4/4 d), sandy clay; weak medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; common fine; slightly effervescent; abrupt smooth boundary.
Btss	alluvial	18-35	Very dark grayish brown (10YR 3/2 d); strong fine angular blocky; very hard, very firm, sticky, plastic; common fine; common prominent cutans on ped faces; very slightly effervescent; abrupt smooth boundary..
BC	alluvial	35-53	Yellowish brown (10YR 5/4 d), fine; hard, friable, nonsticky, nonplastic; no reaction; clear smooth boundary.
Ab	alluvial	53-56	Very dark brown (10YR 3/2 d) sandy clay loam; moderate fine subangular blocky structure; slightly hard, friable, slightly sticky, nonplastic; no reaction; abrupt smooth boundary.
C	alluvial	56-60	Yellowish brown (10YR 5/4 d), fine sand; clear smooth boundary.
Ab2	alluvial	60-63	Very dark brown (10YR 3/2 d) sandy clay loam; moderate fine subangular blocky; slightly hard, friable, slightly sticky, nonplastic; noneffervescent; abrupt smooth boundary.

C2	alluvial	63-69	Yellowish brown (10YR 5/4 d), fine sand; noneffervescent; clear smooth boundary.
C3	alluvial	69-165	Yellowish brown (10YR 5/4 d), moderately sorted, very coarse sand; noneffervescent.

CORE 22
Total Depth: 391 cm
Landform: T1

Stratum	Stratum	Depth (cm)	Description
A1	eolian	0-4	Dark grayish brown (10YR 4/2 d) sandy clay loam; weak fine subangular blocky structure; slightly hard, very friable, nonsticky, nonplastic; common fine; very slightly effervescent; clear smooth boundary.
A2	eolian	4-10	Yellowish brown (10YR 5/4 d) sandy clay loam; weak fine subangular blocky structure; slightly hard, very friable, nonsticky, nonplastic; common fine; very slightly effervescent; clear smooth boundary.
2Bk	alluvial	10-40	Yellowish brown (10YR 5/4 d) sandy clay loam; moderate fine subangular blocky; slightly hard, friable, nonsticky, nonplastic; mottles: yellowish red (5YR 5/6 m); common medium irregular segregated carbonate filaments; very strongly effervescent; abrupt smooth boundary.
2C	alluvial	40-63	Yellowish brown (10YR 5/4 d) moderately sorted, coarse sand; slightly effervescent; clear smooth boundary.
2C2	alluvial	63-79	Yellowish brown (10YR 5/4 d) moderately sorted, very coarse sand; noneffervescent; clear smooth boundary.
2Abt	alluvial	79-85	Dark yellowish brown (10YR 4/4 d) sandy clay; strong coarse angular blocky structure; hard, firm, sticky, plastic; many distinct cutans on ped faces; very strongly effervescent; clear smooth boundary.
2C2	alluvial	85-110	Yellowish brown (10YR 5/4 d) moderately sorted, coarse sand, (10YR 4/4 m); slightly effervescent; clear smooth boundary.
2C3	alluvial	110-203	Yellowish brown (10YR 5/4 d) moderately sorted, very coarse sand; noneffervescent.

CORE 23
Total Depth: 65 cm
Landform: T0

Stratum	Stratum	Depth (cm)	Description
A	alluvial	0-15	Dark brown (10YR 3/3 d) silty clay, dark brown (10YR 3/2 m); moderate medium angular blocky structure; slightly effervescent; clear smooth boundary.
C	alluvial	15-61	Yellowish brown (10YR 5/4 d) well sorted, very coarse sand; slightly effervescent.

CORE 24
Total Depth: 244 cm
Landform: T2

Soil Horizon	Stratum	Depth (cm)	Description
A	eolian	0-12	Dark brown (10YR 3/3 d) silt loam; moderate medium subangular blocky structure; slightly hard, friable, nonsticky, nonplastic; very slightly effervescent; clear smooth boundary.
Bw	eolian	12-30	Yellowish brown (10YR 5/4 d) sandy clay loam; weak fine subangular blocky; slightly hard, friable, nonsticky, nonplastic; very slightly effervescent; clear smooth boundary.
C	alluvial	30-45	Yellowish brown (10YR 5/4 d) moderately sorted coarse sand; noneffervescent; abrupt smooth boundary.
Abk	alluvial	45-50	Yellowish brown (10YR 4/4 d) sandy clay loam; strong medium angular blocky; hard, firm, slightly sticky, slightly plastic; few fine; many fine soft carbonate masses; strongly effervescent; abrupt smooth boundary.
C2	alluvial	50-77	Yellowish brown (10YR 5/4 d) moderately sorted, coarse sand; slightly effervescent; abrupt smooth boundary.
Abtk	alluvial	77-100	Brown (10YR 3/3 d) silty clay, 5% gravel; strong medium angular blocky structure; hard, firm sticky, plastic; common distinct cutans on ped faces; strongly effervescent; clear smooth boundary.
C3	alluvial	100-195	Yellowish brown (10YR 5/4 d) moderately sorted, very coarse sand; slightly effervescent.

CORE 25
Total Depth: 395 cm
Landform: T2

Stratum	Stratum	Depth (cm)	Description
A	eolian	0-10	Dark greyish brown (10YR 4/2) sandy clay; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky, nonplastic; many coarse roots; very slightly effervescent; clear smooth boundary.
Bw	eolian	10-30	Brown (10YR 5/3 d) sandy loam; weak fine subangular blocky structure; slightly hard, very friable, nonsticky, nonplastic; few fine roots; clear smooth boundary.
C	alluvial	30-63	Brown (10YR 5/3 d) well sorted, coarse sand; noneffervescent; abrupt smooth boundary.
2Abk	alluvial	63-75	Brown (10YR 5/3 d) sandy clay; moderate coarse angular blocky structure; hard, firm, sticky, plastic; common coarse soft irregular carbonate masses; very strongly effervescent; clear smooth boundary.
2C	alluvial	75-131	Brown (10YR 5/3 d) well sorted, coarse sand; noneffervescent; abrupt smooth boundary.
2C2	alluvial	131-174	Brown (10YR 5/3 d), moderately sorted, coarse sand; noneffervescent.

CORE 26
Total Depth: 131 cm
Landform: T0

Stratum	Stratum	Depth (cm)	Description
A	alluvial	0-10	Dark grayish brown (10YR 4/2 d), sandy clay; moderate medium angular blocky structure; hard, friable, sticky, plastic; few faint cutans on ped faces; noneffervescent; abrupt smooth boundary.
C	alluvial	11-51	Yellowish brown (10YR 5/4 d) well sorted, very coarse; noneffervescent.

CORE 27
Total Depth: 222 cm
Landform: T0

Stratum	Stratum	Depth (cm)	Description
A	alluvial	0-10	Brown (10YR 4/3 d) sandy clay loam; weak fine subangular blocky structure; slightly hard, friable, slightly sticky, non plastic; common fine; slightly effervescent; abrupt smooth boundary.

C	alluvial	10-21	Yellowish brown (10YR 5/4 d) well sorted, very coarse sand; noneffervescent.
C2	alluvial	21-68	Yellowish brown (10YR 5/4 d) poorly sorted very coarse sand; noneffervescent; clear smooth boundary.
Abt	alluvial	68-73	Brown (10YR 4/3 d) sandy clay, dark brown (10YR 3/3 m); strong coarse angular blocky structure; hard, friable, sticky, plastic; few distinct cutans on ped faces; mottles: yellowish red (5YR 5/6 m); slightly effervescent; clear smooth boundary.
C3	alluvial	73-97	Yellowish brown (10YR 5/4 d) poorly sorted, very coarse sand; noneffervescent.

CORE 28
Total Depth: 222 cm
Landform: T1

Stratum	Stratum	Depth (cm)	Description
A	eolian	0-10	Dark greyish brown (10YR 4/2 d) sandy clay loam, moderate medium subangular blocky structure; slightly hard, very friable, nonsticky, nonplastic; few fine roots; slightly effervescent; clear smooth boundary.
2C	alluvial	10-17	Yellowish brown (10YR 5/4 d) well sorted, coarse sand; noneffervescent; clear smooth boundary.
2C2	alluvial	17-26	Yellowish brown (10YR 5/4 d) moderately sorted, coarse sand; noneffervescent; clear smooth boundary.
2C3	alluvial	26-104	Yellowish brown (10YR 5/4 d), moderately sorted, coarse sand; noneffervescent.

SAND CREEK MASSACRE SITE APRIL/MAY 1999, AUGUST

Core: RC#1
Total Depth: 204 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-25	Dark grayish brown (10YR 4/2 m) well-sorted, coarse sandy clay loam; weak fine subangular blocky structure; strongly effervescent, disseminated; clear smooth boundary.
Bw	eolian	25-63	Dark yellowish brown (10YR 4/4 m) moderately to well-sorted, coarse sandy loam; weak fine granular structure; strongly effervescent, disseminated; abrupt smooth boundary.

2C	alluvial	63-119	Dark yellowish brown (10YR 4/4 m) poorly-sorted, coarse sand, pebbles (25% and 3.3 mm; s=.7, r=.5); very slightly effervescent.

Core: RC#2
Total Depth: 140 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Suface (cm)	Description
A	eolian	0-12	Brown (10YR 4/3 m) well-sorted, coarse sandy clay loam; weak fine subangular blocky structure; strongly effervescent, disseminated; clear smooth boundary.
Bw	eolian	12-48	Dark yellowish brown (10YR 4/4 m) moderately to well-sorted, coarse sandy clay loam; weak subangular blocky structure; strongly effervescent, disseminated; abrupt smooth boundary.
2C	alluvial	48-68	Dark yellowish brown (10YR 4/4 m) poorly-sorted, very coarse to coarse sand (s=.7, r-.5);slightly effervescent; clear smooth boundary.
2Abtk	alluvial	68-98	Very dark grayish brown (10YR 3/2 m) sandy clay; moderate medium subangular blocky structure; common thin cutans on ped faces; many carbonates (35%) medium soft masses, violently effervescent; abrupt smooth boundary. *Radiocarbon sample taken (bulk soil humates)
2C2	alluvial	98-112	Brown (7.5YR 4/4 m) poorly-sorted, very coarse sand; slightly effervescent, clear smooth boundary.
2Ab	alluvial	112-120	Very dark grayish brown (10YR 3/2 m) gravelly sandy clay loam; noneffervescent; clear smooth boundary.
2C3	alluvial	120-140	Pale Brown (10YR 6/3 m) gravelly poorly-sorted coarse sand; noneffervescent.

Core: RC#3
Total Depth: 92 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Suface (cm)	Description
A	eolian	0-25	Brown (10YR 4/3 m) well-sorted, coarse sandy clay loam; weak fine subangular blocky structure; strongly effervescent, disseminated; clear smooth boundary.
C	eolian	25-36	Brown (10YR 5/3 m) well-sorted, coarse sand; slightly effervescent; abrupt smooth boundary.

Abk	eolian	36-47	Dark grayish brown (10YR 4/4 m) sandy clay loam; weak fine subangular blocky structure; common carbonates (4%) fine soft masses, violently effervescent. *Radiocarbon sample taken (bulk soil humates)
2C	alluvial	47-92	Pale brown (10YR 6/3 m) gravelly, poorly-sorted coarse sand, granules (40%, s=.9, r=.5)

DAWSON #2

Core: D2#1
Total Depth: 131 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-20	Brown (10YR 5/3 m) well-sorted sandy clay loam; weak fine subangular blocky structure; strongly effervescent; clear smooth boundary.
C	eolian	20-35	Brown (10YR 4/3 m)moderately sorted coarse sand; no reaction. Abrupt smooth boundary.
Ab	eolian	35-42	Very dark grayish brown (10YR 3/3 m) sandy clay loam; moderate medium subangular blocky structure; no reaction.
2C	alluvial	42-85	Pale brown (10YR 6/3 d) poorly sorted coarse sands, pebbles (5%, 10 mm) and granules (>50%, mm), s=.7, r-.1; no reaction.

Core: D2#2
Total Depth: 227 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-20	Brown (10YR 5/4 m) sandy clay loam; weak medium subangular blocky; strongly effervescent; clear smooth boundary.
C	eolian	20-77	Pale brown (10YR 6/3 m) well-sorted, coarse sand; slightly effervescent; abrupt smooth boundary.
2C	alluvial	77-185	Pale brown (10YR 6/3 m) poorly-sorted, coarse sand, granule (30%)

Core: D2#3
Total Depth: 250 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-24	Olive brown (2.5Y 4/4 m) medium sandy clay loam; weak medium subangular blocky structure; strongly effervescent; clear smooth boundary.
A2	eolian	24-31	Olive brown (2.5Y 4/4 m) medium sandy clay loam; weak medium granular structure; strongly effervescent; clear smooth boundary.
Bw	eolian	31-49	Brown (10YR 5/3 m) well-sorted, fine sandy loam; moderate medium subangular blocky structure; strongly effervescent; abrupt smooth boundary.
2Ab	alluvial	49-55	Olive brown (2.5Y 4/3 m) sandy clay loam; moderate medium subangular blocky structure; strongly effervescent; clear smooth boundary.
2Bwb	alluvial	55-70	Olive brown (2.5Y 4/3 m) sandy clay loam; weak fine subangular blocky structure; strongly effervescent; clear smooth boundary.
2C	alluvial	70-95	Dark olive brown (2.5Y 5/3 m) poorly sorted, coarse sand, granules (4 mm, 10%), pebbles (7 mm, 3%) s=.5, r=.1; no reaction; clear smooth boundary.
2Abtk	alluvial	95-104	Dark olive brown (2.5Y 3/3 m) gravelly sandy clay; moderate coarse subangular blocky structure; fine moderately thick clay cutans on ped faces; few distinct mottles, yellowish red (5YR 5/6 m); clear smooth boundary.
2AC	alluvial	104-115	Dark olive brown (2.5Y 3/3 m) granule/pebble lens, (75% granules, 25% pebbles; R=.1, s=.7); abrupt smooth boundary.
2C2	alluvial	115-182	Dark olive brown (2.5Y 3/3 m) poorly sorted, very coarse sand; granules (4 mm, 20%), pebbles (8 mm, 7%); noneffervescent.

Core: D2#3A
Total Depth: 128 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-20	Olive brown (2.5Y 4/3 m) sandy clay loam; weak fine subangular blocky structure; violently effervescent; clear smooth boundary.

C	eolian	20-32	Pale yellow (2.5Y 7/3 m) well sorted, coarse sand; violently effervescent; clear smooth boundary.
C2	eolian	32-70	Pale yellow (2.5Y 7/3 m) well sorted, fine sand; violently effervescent; abrupt smooth boundary.
2C	alluvial	70-110	Pale yellow (2.5Y 7/3 m) poorly sorted, very coarse sand, granules (3 mm, 5%, s=.7 r=.9); strongly effervescent; clear smooth boundary.
2Abk	alluvial	110-116	Light olive brown (2.5Y 5/3 m) sandy clay loam; common distinct mottles, yellowish red (5YR 6/5 m); violently effervescent.

Core: D2#4
Total Depth: 104 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-14	Olive brown (2.5Y 4/3 m) sandy clay loam; weak fine subangular blocky structure; violently effervescent; gradual smooth boundary.
A2	eolian	14-29	Light olive brown (2.5Y 5/4 m) sandy clay loam; weak fine subangular blocky structure; violently effervescent; clear smooth boundary.
Bw	eolian	29-71	Light olive brown (2.5Y 5/3 m) fine sandy loam; moderate coarse subangular blocky structure; violently effervescent; abrupt smooth boundary.
2Ab	alluvial	71-80	Olive brown (2.5Y 4/3 m) sandy clay loam; moderate medium subangular blocky structure; strongly effervescent; clear smooth boundary.
2C	alluvial	80-104	Light yellowish brown (2.5Y 6/4 m) poorly sorted coarse sand, gravel (7 mm, 50% r=.1, s=.7)

Core: D2#5
Total Depth: 179 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-15	Dark olive brown (2.5Y 3/3 m) sandy clay loam; moderate fine subangular blocky; violently effervescent; gradual smooth boundary.

Bw	alluvial	15-32	Dark grayish brown (2.5Y 4/2 m) silty clay loam; weak fine subangular blocky structure; violently effervescent; gradual smooth boundary.
C	alluvial	32-61	Olive brown (2.5Y 4/3 m) moderately sorted sandy clay loam; strongly effervescent; gradual smooth boundary.
C2	alluvial	61-87	Olive brown (2.5Y 4/3 m) moderately sorted sandy clay loam; strongly effervescent; abrupt smooth boundary.
Ab	alluvial	87-100	Dark olive brown (2.5Y 3/3 m) silty clay; weal fine subangular blocky structure; strongly effervescent; clear smooth boundary.
C3	alluvial	100-110	Light olive brown (2.5Y 5/3 m) moderately sorted coarse sandy loam; massive structure; slightly effervescent; clear smooth boundary.
Ab2	alluvial	110-136	Dark olive brown (2.5Y 3/3 m) silty clay; weak fine subangular blocky structure; strongly effervescent; abrupt smooth boundary.
C4	alluvial	136-179	Grayish brown (2.5Y 5/2 m) poorly sorted, very coarse sand, gravel (50%; r=.5, s=.9); noneffervescent.

Core: D2#6
Total Depth: 118 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-12	Dark grayish brown (2.5Y 4/2 m) silty clay, 1% granules; weak fine subangular blocky structure; strongly effervescent; clear smooth boundary.
AE	alluvial	12-17	Grayish brown (2.5Y 5/2 m) sandy clay loam, 1% granules; weak fine granular structure; strongly effervescent; clear smooth boundary.
Bt (weak)	alluvial	17-38	Olive brown (2.5Y 4/3 m) silty clay; moderate coarse subangular blocky structure; strongly effervescent; clear smooth boundary.
C	alluvial	38-52	Light yellowish brown (2.5Y 6/3 m) poorly sorted, very coarse sand, 5% gravel; very slightly effervescent; abrupt smooth boundary.
Ab	alluvial	52-55	Dark olive brown (2.5Y 3/3 m) poorly sorted, very coarse sands in a silty clay matrix; weak fine subangular blocky structure; strongly effervescent; abrupt smooth boundary.

C2	alluvial	55-91	Light yellowish brown (2.5Y 6/3 m) poorly sorted, very coarse alluvial sand, r=.7, s=.5; slightly effervescent; clear boundary.
Ab2	alluvial	91-95	Olive brown (2.5Y 4/3 m) poorly sorted, very coarse alluvial sand in a silty clay matrix; strongly effervescent; clear smooth boundary.
C3	alluvial	95-118	Light yellowish brown (2.5Y 6/3 m) poorly sorted, very coarse alluvial sand, r=.7, s=.5; slightly effervescent; clear boundary.

Core: D2#7
Total Depth: 257 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-7	Light olive brown (2.5Y 5/3 m) silty clay loam; moderate fine subangular blocky structure; strongly effervescent; clear smooth boundary.
Bw	alluvial	7-39	Dark grayish brown (2.5Y 4/2 m) silty clay loam; moderate fine subangular blocky structure; strongly effervescent; clear smooth boundary.
C	alluvial	39-63	Light olive brown (2.5Y 5/4 m) medium sandy loam; slightly effervescent; clear smooth boundary.
Ab	alluvial	63-75	Dark olive brown (2.5Y 3/3 m) silty clay; moderate fine subangular blocky structure; strongly effervescent; clear smooth boundary.
C2	alluvial	75-160	Light yellowish brown (2.5Y 6/4 m) poorly sorted, very coarse sand, r=.5 s=.7, gravel (75%); strongly effervescent.

Core: D2#8
Total Depth: 254 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-5	Very dark grayish brown (2.5Y 3/2 m)sandy clay loam; moderate fine subangular blocky structure; strongly effervescent; clear smooth boundary.
Bw	alluvial	5-30	Olive brown (2.5Y 4/4 m) silty clay loam; moderate fine subangular blocky structure; strongly effervescent; gradual smooth boundary.

Bw2	alluvial	30-77	Olive brown (2.5Y 4/4 m) silty clay loam (slightly more clay); moderate fine subangular blocky structure; strongly effervescent; gradual smooth boundary.
C	alluvial	77-133	Light olive brown (2.5Y 5/3 m) moderately sorted coarse sand, 10% gravel (r=.9, s=.5); strongly effervescent; clear smooth boundary.
C2	alluvial	133-185	Light olive brown (2.5Y 5/3 m) poorly sorted, very coarse sand, 90% gravel (r=.9, s=.9); noneffervescent.

Core: D2#9
Total Depth: 209 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-5	Dark grayish brown (2.5Y 4/2 m) sandy clay loam; weak fine subangular blocky structure; strongly effervescent; gradual smooth boundary.
Bw	alluvial	5-40	Light olive brown (2.5Y 5/3 m) silty clay loam; weak fine subangular blocky structure; strongly effervescent; gradual smooth boundary.
2Ab	alluvial	40-102	Dark grayish brown (2.5Y 4/2 m) silty clay; weak fine subangular blocky structure; strongly effervescent; gradual smooth boundary.
2Ab-Bkb	alluvial	102-140	Light olive brown (2.5Y 5/3 m) silty clay; strong coarse subangular blocky structure; common carbonates (4%), fine irregular segregated filaments, violently effervescent; clear smooth boundary.
2C	alluvial	140-170	Light yellowish brown (2.5Y 6/3 m) poorly sorted, coarse sand; slightly effervescent.
2C2	alluvial	>170	Light yellowish brown (2.5Y 6/3 m) poorly sorted, coarse sand, granule (80%) s=.5, r=.7; noneffervescent.

Core: D2#9A
Total Depth: 209 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-6	Dark grayish brown (2.5Y 4/2 m) sandy clay loam; weak fine subangular blocky structure; strongly effervescent; gradual smooth boundary.

Bw	alluvial	6-27	Very dark grayish brown (2.5Y3/2 m) sandy clay loam; weak fine subangular blocky structure; strongly effervescent; gradual smooth boundary.
C	alluvial	27-50	Light yellowish brown (2.5Y 6/3 m) moderately sorted, coarse sand; strongly effervescent; clear smooth boundary.
Ab	alluvial	50-55	Dark grayish brown (2.5Y 4/2 m) silty clay; weak fine subangular blocky structure; violently effervescent; clear smooth boundary.
C2	alluvial	55-85	Light yellowish brown (2.5Y 6/3 m) moderately sorted, coarse sand; strongly effervescent; abrupt smooth boundary.
Ab2	alluvial	85-100	Very dark grayish brown (2.5Y3/2 m) silty clay; moderate fine subangular blocky structure; common (5%) thin clay cutans on ped faces; common carbonates (5%) fine irregular segregated filaments; violently effervescent; gradual smooth boundary.
C3	alluvial	100-113	Light olive brown (2.5Y 5/3 m) moderately sorted coarse sand; slightly effervescent; clear smooth boundary.
Ab-Bkb	alluvial	113-140	Light olive brown (2.5Y 5/3 m) silty clay; moderate medium subangular blocky structure; common carbonates (3%) fine irregular segregated filaments, violently effervescent; gradual smooth boundary.
C4	alluvial	140-180	Light yellowish brown (2.5Y 6/3 m) poorly sorted, coarse sand, 20% granule; slightly effervescent; abrupt smooth boundary.
C5	alluvial	180-200	Light yellowish brown (2.5Y 6/3 m) poorly sorted, very coarse sand, s=.7, r=.3; noneffervescent.

Core: D2#10
Total Depth: 270 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-17	Olive brown (2.5Y 4/3 m) silty clay loam; weak fine granular structure; violently effervescent; gradual smooth boundary.
Bw	alluvial	17-69	Olive brown (2.5Y 4/3 m) silty clay loam; weak medium subangular blocky structure; violently effervescent; clear smooth boundary.
C	alluvial	69-140	Light yellowish brown (2.5Y 6/3 m) poorly sorted, coarse sand, granule (30%), r=.5, s=.7; violently effervescent; clear smooth boundary.

C2	alluvial	140-210	Light olive brown (2.5Y 5/4 m) poorly sorted, very coarse sand, gravel (5%); noneffervescent.

Core: D2#11
Total Depth: 270 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-16	Olive brown (2.5Y 4/3 m) sandy clay loam; weak fine granular structure; strongly effervescent; clear smooth boundary.
2Ab	alluvial	16-42	Dark olive brown (2.5Y 3/3 m) moderately sorted, sandy clay loam; violently effervescent; clear smooth boundary.
2C	alluvial	42-125	Light yellowish brown (2.5Y 6/3 m) moderately sorted, (10% granule) coarse sand, s=.5, r=.7; slightly effervescent.
2C2	alluvial	125-138	Light yellowish brown (2.5Y 6/3 m) poorly sorted, very coarse sand, s=.5, r=.7; slightly effervescent.

Core: D2#12 ^{14}C
Total Depth: 321 cm
Landform: T3- "spring" grass area

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-33	Dark grayish brown (2.5Y 4/2 m) sandy clay loam; weak fine subangular blocky structure; strongly effervescent; gradual smooth boundary.
Bw	eolian	33-110	Olive brown (2.5YR 4/3 m) silty clay loam; moderate fine subangular blocky structure; strongly effervescent; clear smooth boundary.
Bkb	eolian	110-150	Light olive brown (2.5Y 5/3 m) sandy clay loam; strong coarse subangular blocky structure; common carbonates (10%) medium irregular segregated filaments, violently effervescent; diffuse boundary.
Bkb2	eolian	150-175	Olive brown (2.5Y 4/4 m) sandy clay loam; moderate medium subangular blocky structure; common carbonates (7%) fine irregular filaments, violently effervescent; clear smooth boundary.
Bkb3	eolian	175-230	Olive brown (2.5YR 4/3 m) sandy clay loam; moderate medium subangular blocky structure; many carbonates (>50%) medium irregular soft masses- groundwater, violently effervescent; abrupt smooth boundary.

Abk	eolian	230-257	14C. Very dark grayish brown (2.5Y 3/2 m) silty clay; moderate medium subangular blocky structure; many carbonates (>50%) medium irregular soft masses-groundwater, violently effervescent; clear smooth boundary.
Bkb4	eolian	257-290	Olive brown (2.5Y 4/4 m) sandy clay loam; moderate medium subangular blocky structure; many carbonates (30%) medium irregular soft masses, violently effervescent; clear smooth boundary.
Bkb5	eolian	290-317	Light brownish gray (2.5Y 6/2 m) sandy clay loam; moderate medium subangular blocky structure; many (30%) medium irregular soft carbonate masses, violently effervescent; diffuse boundary.
Bgb	eolian	317-321	Greenish grey (Gley 1, 5/10Y matrix) light greenish gray (Gley 1, 7/10Y, mottle) silty clay; common prominent mottles; noneffervescent.

Core: D2#13
Total Depth: 275 cm
Landform: T2, 117.5 m 85 degrees from N

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-40	Olive brown (2.5Y 4/3 m) sandy clay loam; weak coarse subangular blocky; strongly effervescent; diffuse boundary.
Bw	eolian	40-75	Olive brown (2.5Y 4/3 m) silty clay loam; weak coarse subangular blocky; strongly effervescent; diffuse boundary.
Bk	eolian	75-275	Light olive brown (2.5Y 5/4 m) silty clay loam; weak coarse subangular blocky structure; many carbonates (30%) medium irregular soft masses, violently effervescent; clear smooth boundary. Towards the bottom, granule sized salt crystals-gypsum?
C	eolian	275-295	Light yellowish brown (2.5Y 6/3 m) poorly sorted, coarse sand; noneffervescent.

BOWEN #1
Core: B1#1
Total Depth: 309 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-7	Olive brown (2.5Y 4/3 m) sandy clay loam; weak coarse subangular blocky; few carbonates (1%) fine irregular segregated filaments, strongly effervescent; diffuse boundary.

Bw	alluvial	7-46	Olive brown (2.5Y 4/3 m) silty clay loam; weak coarse subangular blocky; strongly effervescent; diffuse boundary.
Bt	alluvial	46-92	Olive brown (2.5Y 4/3 m) silty clay; weak medium subangular blocky structure; few (1%) moderately thick clay cutans on ped faces; many carbonates (25%) medium irregular segregated filaments, violently effervescent; clear smooth boundary.
Bk	alluvial	92-265	Olive brown (2.5Y 4/3 m) sandy clay loam; weak fine subangular blocky structure; many (20%) medium irregular soft carbonate masses, common (10%) fine irregular segregated carbonate filaments, violently effervescent; clear smooth boundary.
Abk	alluvial	265-280	Dark grayish brown (2.5Y 4/2 m) sandy clay loam; moderate fine subangular blocky structure; common (10%) fine irregular segregated carbonate filaments, strongly effervescent; clear smooth boundary.
C	alluvial	280-308	Light yellowish brown (2.5Y 6/3 m)sandy loam; common (7%) fine irregular soft carbonate masses, strongly effervescent; clear smooth boundary.
C2	alluvial	308-309	Olive brown (2.5Y 4/3 m) moderately sorted, very coarse sand; noneffervescent.

Core: B1#2
Total Depth: 374 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-3	disturbed
Bw	alluvial	3-25	Light olive brown (2.5Y5/3 m) silty clay loam; weak fine subangular blocky structure; granules (7%); violently effervescent; clear smooth boundary
Bw2	alluvial	25-85	Light olive brown (2.5Y5/3 m) silty clay loam (more clay than above); weak fine subangular blocky structure; violently effervescent; clear smooth boundary.
Bkb	alluvial	85-115	Light yellowish brown (2.5Y 6/3 m) medium sandy loam; weak coarse subangular blocky structure; many (25%) fine irregular segregated carbonate filaments, common (15%) medium irregular soft carbonate masses, violently effervescent; clear smooth boundary.
C	alluvial	115-210	Light olive brown (2.5Y 5/3 m) coarse sandy clay loam; common (20%) fine irregular soft carbonate masses, violently effervescent; clear smooth boundary.

C2	alluvial	210-250	Light olive brown (2.5Y 5/3 m) poorly sorted, very coarse sand, 2% gravel, s=.7 r=.9; violently effervescent; clear smooth boundary.
C3	alluvial	250-280	Light olive brown (2.5Y 5/3 m) poorly sorted, very coarse sand, noneffervescent; clear smooth boundary.
C4	alluvial	280-290	Light olive brown (2.5Y 5/3 m) poorly sorted, medium sandy loam; noneffervescent; clear smooth boundary
C5	alluvial	290-320	Light olive brown (2.5Y 5/3 m) poorly sorted, very coarse sand, 5% gravel; noneffervescent; clear smooth boundary.
C6	alluvial	320-331	Light olive brown (2.5Y 5/3 m)well sorted medium sand, 5% gravel; noneffervescent.

Core: B1#3
Total Depth: 309 cm
Landform: T3

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	eolian	0-13	Light olive brown (2.5Y5/3 m) sandy clay loam; moderate fine subangular blocky structure; violently effervescent; gradual smooth boundary.
Bw	eolian	13-50	Light olive brown (2.5Y5/3 m) sandy clay loam; weak fine subangular blocky structure; violently effervescent; gradual smooth boundary.
Bkb	eolian	50-110	Light olive brown (2.5Y5/3 m) silty clay loam; weak coarse subangular blocky structure; many (27%) medium irregular carbonate filaments and many (22%) medium irregular soft carbonate masses, violently effervescent; gradual smooth boundary.
Bkb2	eolian	110-151	Light olive brown (2.5Y5/3 m) silty clay loam; weak medium subangular blocky structure; common (15%) irregular segregated carbonate filaments, common (10%) salt crystals-gypsum?; clear smooth boundary.
2C	alluvial	151-157	Light olive brown (2.5Y5/3 m) moderately sorted coarse-very coarse sand; strongly effervescent; clear smooth boundary.
2C2	alluvial	157-166	Light olive brown (2.5Y5/3 m) well sorted silty clay loam; massive structure; violently effervescent; clear smooth boundary.
2C3	alluvial	166-171	Light olive brown (2.5Y5/3 m) moderately sorted coarse-very coarse sand; strongly effervescent; clear smooth boundary.

2Bkb	alluvial	171-243	Light olive brown (2.5Y5/3 m) silty clay loam; weak medium subangular blocky structure; common (15%) irregular segregated carbonate filaments, common (10%) irregular soft carbonate masses, 7% crystals, violently effervescent; clear smooth boundary.
2C4	alluvial	243-282	Light olive brown (2.5Y5/3 m) moderately sorted sandy clay loam, 10% very coarse sand and granule; clear smooth boundary.
2C5	alluvial	282-292	Light olive brown (2.5Y5/3 m) silty clay loam; massive structure; violently effervescent; abrupt smooth boundary.
2C6	alluvial	292-303	Light olive brown (2.5Y5/3 m) moderately sorted coarse sandy clay loam; massive structure; strongly effervescent; abrupt smooth boundary.
2C7	alluvial	303-314	Light olive brown (2.5Y5/3 m) silty clay loam; massive structure; common (20%) medium irregular soft carbonate masses, violently effervescent; abrupt smooth boundary.
2C8	alluvial	314-322	Light olive brown (2.5Y5/3 m) moderately sorted coarse sandy clay loam; massive structure; strongly effervescent.; abrupt smooth boundary.

Core: B1#4
Total Depth: 296 cm
Landform: T3

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-25	Dark grayish brown (2.5Y 4/2 m) silty clay loam, 5% granule (road disturbance?); moderate medium subangular blocky structure; strongly effervescent; gradual smooth boundary.
Bw	alluvial	25-65	Olive brown (2.5Y 4/3 m) moderately sorted silty clay loam-15% granule; weak fine subangular blocky structure; strongly effervescent; gradual smooth boundary.
Bk	alluvial	65-230	Light olive brown (2.5Y 5/3 m) well sorted medium sandy loam; weak fine subangular blocky structure; common (21%) irregular segregated carbonate filaments; violently effervescent; gradual smooth boundary.
Bk2	alluvial	230-310	Light olive brown (2.5Y 5/3 m) moderately sorted coarse sandy loam; weak fine subangular blocky structure; common (17%) fine irregular segregated carbonate filaments; abrupt smooth boundary.
C	alluvial	310-330	Light olive brown (2.5Y 5/3 m) poorly sorted, very coarse sand, 40% granule; slightly effervescent; abrupt smooth boundary.

C2	alluvial	330-340	Light olive brown (2.5Y 5/3 m) well sorted medium sand; slightly effervescent.

Core: B1#5
Total Depth: 280 cm
Landform: T3

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-25	Light olive brown (2.5Y 5/3 m) silty clay loam; moderate fine subangular blocky structure; strongly effervescent; clear smooth boundary.
Bk	alluvial	25-170	Light olive brown (2.5Y 5/3 m) silty clay loam; weak fine subangular blocky structure; common (20%)fine irregular segregated carbonate filaments, violently effervescent; clear smooth boundary.
C	alluvial	170-180	Light olive brown (2.5Y 5/3 m) poorly sorted, medium sand; strongly effervescent; abrupt smooth boundary.
C2	alluvial	180-220	Light olive brown (2.5Y 5/3 m) silty clay loam; massive structure; strongly effervescent; abrupt smooth boundary.
C3	alluvial	220-280	Light olive brown (2.5Y 5/3 m) poorly sorted coarse sand, gravel (20%) s=.7, r=.9; strongly effervescent.

Core: B1#6
Total Depth: 280 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-10	Very dark grayish brown (2.5Y 3/2 m) silty clay loam, moderate fine subangular blocky structure; strongly effervescent; clear smooth boundary.
Bw	alluvial	10-90	Very dark grayish brown (2.5Y 3/2 m) silty clay loam; weak medium subangular blocky structure; clear smooth boundary.
Bk	alluvial	90-150	Dark gray (2.5Y 4/1 m) silty clay loam, moderate coarse subangular blocky structure; common (10%) fine irregular segregated carbonate filaments, common (20%) medium irregular soft carbonate masses, violently effervescent; clear smooth boundary.

Btk	alluvial	150-240	Very dark gray (2.5Y 3/1 m) silty clay; weak medium angular blocky structure; many (>50%) medium irregular soft carbonate masses; common (10%) distinct mottles, light olive brown (2.5Y 5/6 m); common (5%) moderately thick clay cutans on ped faces; violently effervescent; clear smooth boundary.
Btk2	alluvial	240-270	Very dark gray (2.5Y 3/1 m) silty clay (more than above); weak medium angular blocky structure; common (10%) moderately thick clay cutans on ped faces; common prominent mottles, strong brown (7.5Y 4/6 m); violently effervescent; clear smooth boundary.
Bt	alluvial	270-330	Dark grayish brown (2.5Y 4/2 m) silty clay; moderate medium subangular blocky structure; common (15%) moderately thick clay cutans on ped faces; common distance mottles, light olive brown (2.5Y 5/6 m); slightly effervescent.

Core: B1#7
Total Depth: 262 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvium	0-24	Olive brown (2.5Y 4/3 m) silty clay loam; moderate medium subangular blocky structure; strongly effervescent; clear smooth boundary.
Ab	alluvium	24-57	Olive brown (2.5Y 4/3 m) silty clay loam; weak fine subangular blocky structure; strongly effervescent clear smooth boundary.
Bwb	alluvium	57-80	Black (2.5Y 2.5/1 m) silty clay loam; weak coarse angular blocky structure; strongly effervescent; clear smooth boundary.
Bwb2	alluvium	80-130	Olive brown (2.5Y 4/3 m) silty clay loam; weak coarse subangular blocky; strongly effervescent; clear smooth boundary.
Abk	alluvium	130-180	Very dark grayish brown (2.5Y 3/2 m) silty clay; weak fine angular blocky structure; many (30%) fine irregular soft carbonate masses; common (5%) moderately thick clay skins on ped faces; common (25%) distinct iron nodules; violently effervescent; clear smooth boundary.
Bg	alluvium	180-230	Dark greenish grey (gley 1, 4/10Y) silty clay; moderate medium subangular blocky; common (20%) prominent mottles, strong brown (7.6YR 5.6 m); slightly effervescent.

C	alluvial	105-120	Dark brown (10YR 4/3 m) moderately sorted medium sand; slightly effervescent; clear smooth boundary.
Ab	alluvial	120-122	Dark grayish brown (10YR 4/2 m) silty clay; slightly effervescent; abrupt smooth boundary.
C	alluvial	122-189	Yellowish red (5YR 5/6 m) moderately sorted coarse sand; common distinct mottles, dark brown (7.5YR 4/4 m).

10, 11, 12 were not dug.

Core: B1#13
Total Depth: 189 cm
Landform: T3

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-15	Dark brown (10YR 4/ m) sandy clay loam; weak fine subangular blocky structure; slightly effervescent; clear smooth boundary.
Bw	alluvial	15-56	Yellowish brown (10YR 5/4 m) silty clay loam; weak medium subangular blocky structure; violently effervescent; clear smooth boundary.
Bw2	alluvial	56-100	Yellowish brown (10YR 5/4 m) fine sandy clay loam; weak fine subangular blocky structure; strongly effervescent; clear smooth boundary.
Bk	alluvial	100-135	Pale brown (10YR 6/3 m) fine sandy clay loam; moderate coarse subangular blocky structure; common (15%) fine irregular segregated carbonate filaments; violently effervescent.
Bk2	alluvial	135-250	Yellowish brown (10YR 5/4 m) fine sandy clay loam; weak medium subangular blocky structure; common (15%) fine irregular segregated carbonate filaments; few (2%) fine irregular soft carbonate masses; clear smooth boundary.
C	alluvial	250-310	Yellowish brown (10YR 5/4 m) poorly sorted medium sand; strongly effervescent.

Core: B1#14
Total Depth: 189 cm
Landform: T3, almost on T2/T3 riser

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-15	Dark grayish brown (10YR 4/2 m) sandy clay loam; weak fine subangular blocky structure; slightly effervescent; gradual smooth boundary.
Bw	alluvial	15-55	Dark grayish brown (10YR 4/2 m) silty clay loam; weak very fine subangular blocky structure; strongly effervescent; gradual smooth boundary.
Bk	alluvial	55-150	Olive brown (10YR 4/4 m) silty clay loam; weak fine subangular blocky structure; common (20%) medium irregular segregated carbonate filaments; violently effervescent; clear smooth boundary.
Bk2	alluvial	150-260	Olive brown (10YR 4/4 m) silty clay loam; weak medium subangular blocky structure; common (10%) fine irregular segregated carbonate filaments; common (10%) fine irregular soft carbonate masses; violently effervescent.

Core: B1#15
Total Depth: 261 cm
Landform: T1-T3 riser

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-30	Dark brown (10YR 4/3 m) silty clay loam; weak fine subangular blocky structure; violently effervescent; gradual smooth boundary.
A2	alluvial	30-59	Dark grayish brown (10YR 4/2 m) silty clay loam; weak fine subangular blocky structure; violently effervescent; gradual smooth boundary.
Bk	alluvial	59-180	Grayish brown (2.5Y 5/3 m) silty clay loam; weak coarse subangular blocky structure; common (10%) fine irregular segregated carbonates; violently effervescent; clear smooth boundary.
Bg	alluvial	180-210	gley 1 6/N moderately sorted coarse sand; matrix 2.5Y 5/6 m) and common distinct mottles 2.5Y 5/6 m)

Core: D3#5
Total Depth: 131 cm
Landform: T1

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial overbank	0-16	very dark grayish brown (10YR 3/2 m) silty clay loam; strongly effervescent, disseminated; clear smooth boundary.
C	alluvial	16-23	Pale brown (10yr 6/3 d) very fine sandy loam; strongly effervescent, disseminated; clear smooth boundary.
Ab ^{14}C	alluvial	23-43	Brown (10YR 4/3 m) very fine sandy loam; strongly effervescent, disseminated; clear smooth boundary.
C2	alluvial channel	43-62	Pale brown (10YR 6/3 m) very fine sandy loam; strongly effervescent, disseminated; clear smooth boundary.
C3	alluvial channel	62-131	Brown (10YR 5/3 m) poorly sorted coarse sand (s=.7, r=.9); noneffervescent.

Core: D3#6
Total Depth: 133 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
Ap	alluvial	0-44	Dark grayish brown (10YR 4/2 m) poorly sorted coarse grained sandy loam; massive; slightly effervescent; clear smooth boundary.
Bk	alluvial	44-65	Brown (10YR 5/3 m) very fine sandy loam; weak fine subangular blocky structure; strongly effervescent, disseminated; clear smooth boundary.
C	alluvial	65-97	Pale brown (10YR 6/3 m) very fine sandy clay loam; strongly effervescent, disseminated; abrupt smooth boundary.
Abk	alluvial	97-133	Dark grayish brown (10YR 4./2 m) silty clay loam; common (19%) fine irregular segregated filaments, violently effervescent.

Core: D3#1
Total Depth: 109 cm
Landform: T1 next to shot cache

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-15	Olive brown (2.5Y 4/3 m) silty clay loam; weak coarse granular structure; strongly effervescent; gradual smooth boundary.
Bw	alluvial	15-58	Dark grayish brown (2.5Y 4/2 m) silty clay loam; weak fine subangular blocky structure; strongly effervescent; gradual smooth boundary.
C	Alluvial	58-65	Light olive brown (2.5Y 5/4 m) poorly sorted coarse and very coarse sand; noneffervescent; clear smooth boundary.
C2	alluvial	65-78	Olive brown (2.5Y 4/3 m) massive, well-sorted sandy clay loam; clear smooth boundary.
C3	alluvial	78-89	Olive brown (2.5Y 4/3 m) massive poorly sorted, very coarse sands.

Core: D3#2
Total Depth: 131 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-5	Brown (10YR 4/3 m) well sorted coarse sandy loam; slightly effervescent; clear smooth boundary.
Bw	alluvial	5-41	Brown (10YR 4/3 m) well sorted, coarse sandy loam; weak medium subangular blocky structure; strongly effervescent; clear smooth boundary.
Bw2	alluvial	41-75	Brown (10YR 4/3 m) moderately sorted medium sandy clay loam; weak fine subangular blocky structure; strongly effervescent; abrupt smooth boundary.
2Abk	alluvial	75-100	Very dark grayish brown (2.5Y 3/2 m) silty clay; moderate medium subangular blocky structure; common (10%) medium irregular segregated carbonate filaments; clear smooth boundary.
2C	alluvial	100-110	Light olive brown (2.5Y 5/3 m) well sorted coarse sand; noneffervescent.
3Abk	alluvial	110-120	Light olive brown (2.5Y 5/3 m) sandy clay loam; common (10%) medium irregular segregated carbonate filaments; clear smooth boundary.

Core: B1#8
Total Depth: 262 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-34	Dark brown (10YR 4/3 m) silty clay loam; weak fine subangular blocky structure; noneffervescent; gradual smooth boundary.
Bw	alluvial	34-70	Dark grayish brown (10YR 4/2 m) silty clay loam; weak fine subangular blocky structure; noneffervescent. clear smooth boundary.
Bw2	alluvial	70-100	Brown (10YR 5/3 m) well-sorted sandy loam; noneffervescent; clear smooth boundary.
Abk	alluvial	100-150	Black (10YR 2/1 m) silt loam; many (30%) fine, irregular segregated carbonate filaments; violently effervescent; common (7%) redox features; noneffervescent; clear smooth boundary.
Abk2	alluvial	150-230	Dark grayish brown (10YR 4/2 m) sandy clay; common (20%) irregular segregated carbonate filaments; violently effervescent. Clear smooth boundary.
Ab	alluvial	230-257	Dark grayish brown (10YR 4/2 m) well-sorted medium sandy clay loam.

Core: B1#9
Total Depth: 189 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-18	Dark grayish brown (10YR 4/2 m) sandy clay loam; weak fine subangular blocky structure; noneffervescent; clear smooth boundary.
Bw	alluvial	18-65	Very dark grayish brown (10YR 3/2 m) silty clay loam; weak fine subangular blocky structure; slightly effervescent; clear smooth boundary.
Bk	alluvial	65-91	Dark grayish brown (10YR 4/2 m) silty clay loam; weak fine angular blocky structure; violently effervescent; clear smooth boundary.
Abk	alluvial	91-105	Dark grayish brown (10YR 4/2 m) silty clay loam; common (10%) irregular segregated carbonate filaments; violently effervescent; clear smooth boundary.

3C	alluvial	120-140	Light olive brown (2.5Y 5/3 m) well sorted medium sand; noneffervescent.
3C2	alluvial	140-160	Light olive brown (2.5Y 5/3 m) well sorted coarse sand; noneffervescent.
3C3	alluvial	160-200	Light olive brown (2.5Y 5/3 m) poorly sorted coarse sand and granule (s=.7, r=.9)

Core: D3#3
Total Depth: 62 cm
Landform: T1

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-40	Very dark grayish brown (2.5Y 3/2 m) silty clay; moderate medium subangular blocky; slightly effervescent; clear smooth boundary.
AC	alluvial	40-50	Light olive brown (2.5Y 4/3 m) sandy clay loam; weak fine subangular blocky; slightly effervescent; clear smooth boundary.
C	alluvial	50-60	Light olive brown (2.5Y 5/3 m) moderately sorted coarse and very coarse sand (s=.7, r=.9); noneffervescent.

Core: D3#4
Total Depth: 130 cm
Landform: T2

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-10	Light olive brown (2.5Y 5/3 m) medium sandy clay loam; weak fine subangular blocky structure; slightly effervescent; clear smooth boundary
C	alluvial	10-45	Light olive brown (2.5Y 5/3 m) well sorted coarse sand; very weak subangular blocky structure; noneffervescent; abrupt smooth boundary.
Ab	alluvial	45-50	Dark grayish brown (2.5Y 4/2 m) well sorted coarse sandy loam; noneffervescent; clear smooth boundary.
C	alluvial	50-70	Light olive brown (2.5Y 5/3 m) poorly sorted, very coarse sand; noneffervescent.

Core: B1#16
Total Depth: 131 cm
Landform: T1

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-14	Very dark grayish brown (10YR 3/2 m) silty clay loam; weak fine subangular blocky structure; slightly effervescent; clear smooth boundary.
Bw	alluvial	14-30	Dark brown (10YR 4/3 m) sandy clay loam; weak fine subangular blocky structure; slightly effervescent; clear smooth boundary.
Btss	alluvial	30-52	Very dark grayish brown (10YR 3/2 m) silty clay; weak medium subangular blocky structure; strongly effervescent; clear smooth boundary.
BC	alluvial	52-85	Dark brown (10YR 4/3 m) silty clay; weak mediums subangular blocky structure; strongly effervescent; clear smooth boundary.
C	alluvial	85-122	Dark brown (10YR 4/3 m) silty clay; common (10%) distinct mottles, Strong brown (7.5YR 5/6)

DAWSON #3
Core: Shot Cache
Total Depth: 23 cm
Landform: T1

Soil Horizon	Stratigraphic Unit	Depth Below Surface (cm)	Description
A	alluvial	0-8	Dark grayish brown (10YR 4/2 m) silty clay loam; weak fine subangular blocky structure; violently effervescent; clear smooth boundary.
Ab	alluvial	8-15	Very dark grayish brown (10YR 3/2 m) medium sandy clay loam; weak fine subangular blocky structure; violently effervescent; abrupt smooth boundary.
C	Alluvial	15-23	Brown (10YR 4/3 m) well sorted, medium sand; strongly effervescent.